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ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY

INSTITUTIONAL PLAN

FY 2004–FY 2008

January 2004

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PREFACE

The Fiscal Year (FY) 2004–2008 Institutional Plan describes the strategic directions and key issues that Lawrence Berkeley National Laboratory management must address with the Department of Energy (DOE) in charting its future as a multiprogram national laboratory. The Plan provides an overview of the Laboratory's mission, strategic plan, initiatives, and the resources required to fulfill its role in support of national needs in fundamental science and technology, energy resources, and environmental quality. The Plan facilitates the Department of Energy's ongoing efforts to strengthen the system of laboratories and operate then under best practices principles.

Preparation and review of the Institutional Plan is one element of the Department of Energy's strategic management planning activities, implemented through an annual planning process. The Plan supports the President's Management Agenda and the Government Performance and Results Act of 1993. The Plan complements the current performance-based contract between the Department of Energy and the Regents of the University of California, and summarizes Best Management Practices for a potential model contract for achieving DOE goals and holding the Laboratory accountable for scientific and operations results. It identifies technical and administrative directions in the context of national energy policy and research needs and the Department of Energy's program planning initiatives. Preparation of the Plan is coordinated by the Planning and Strategic Development Office from information contributed by Berkeley Lab's scientific and support divisions and DOE comments on prior years' plans.

The Laboratory Mission section identifies the specific strengths of Berkeley Lab that contribute to the mission in general and the Laboratory System. The Laboratory Strategic Plan section identifies the Laboratory Science Vision and strategic goals, along with the activities in support of DOE Office of Science and other sponsors. The Initiatives section describes some of the specific new research programs representing major long-term opportunities for the Department of Energy and Berkeley Lab. The Operations Strategic Planning section describes our strategic thinking in the areas of human resources; site and cybersecurity; workforce diversity; communications and trust; integrated safety management; and technology transfer activities. The Infrastructure Strategic Planning section describes Berkeley Lab's facilities planning process and our site and facility needs. The Summary of Major Issues section provides context for discussions at the Institutional Planning On-Site Review. The Resource Projections are estimates of required budgetary authority for Berkeley Lab's research programs.

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I. DIRECTOR'S STATEMENT

This decade holds the promise of scientific advancement that will be of critical importance to the nation's welfare. We are unlocking the human genome, starting a nanoscience revolution, revealing the fate of the universe, and developing a new field of ultrafast science. Our efforts in energy efficiency and geological waste repositories will both improve the environment and help serve our energy future. I am gratified that the advances championed by Berkeley Lab will help maintain U.S. leadership in the physical and natural sciences. Our work strengthens the Department of Energy's (DOE's) missions in science, energy, and security.

Science Vision

At Berkeley Lab our planning and management focus our resources on the most promising research activities. The strategic goals addressed in this plan stretch the limits of scientific capability. They support the Strategic Plan of the Office of Science, as we desire no less than to harness the power of the living world, design energy efficient materials for the future forged at atomic scale, measure dark energy, understand cell machinery and open new capabilities for ultrafast science, and provide powerful research facilities to advance science. Through computational science-of-scale, we will deliver new discoveries at extreme frontiers not possible through experimentation and theory alone.

The science vision for Berkeley Lab is international scientific leadership that gains revolutionary technical knowledge to benefit the nation and the people of the world. We will work jointly with the Office of Science, to refine and further Science Strategic goals with great scope and impact. These Science Strategic Goals include:

- ***Designing new generations of materials with tailored properties.*** Berkeley Lab is constructing a Molecular Foundry to advance the Office of Science role in the National Nanotechnology Initiative. This science research center will focus on both soft and hard nanostructured building blocks and their fabrication into functional multicomponent assemblies. The Foundry will be a user facility for visiting scientists, and will have an internal research program, a training program for students and postdoctoral fellows, and portals to other Berkeley Lab major user facilities, including the Advanced Light Source (ALS), the National Center for Electron Microscopy, and the National Energy Research Scientific Computing Center.
- ***Measuring the most dominant constituent of the universe—dark energy.*** Berkeley Lab is undertaking a research and planning effort for an astrophysics satellite program that will define the fundamental properties of the universe through the observations of supernovae. The effort stems from mounting supernova evidence that the expansion of the universe is accelerating, perhaps driven by an unseen dark energy. The observation of sufficient numbers of supernova events is necessary to measure the mass density, energy density, and curvature of the universe, and to address this newly discovered dark energy. The international collaboration for this satellite mission will require resources for planning and experimental development during the next several years, in advance of project implementation.
- ***Understanding the machinery of cells at the most fundamental levels.*** In the era that follows the sequencing of the human genome, a new biology program for the Office of Science is directed at developing more predictive and quantitative understanding and control of microbiological systems. This includes characterizing the regulatory networks of microorganisms and creating data-driven, validated models of biological responses in environments of critical importance to DOE. Berkeley Lab's efforts are directed towards an integrated program of environmental microbiology, functional genomic measurement, and computational analysis and modeling to

understand the basic biology of microbial systems and to restore contaminated environments. This work complements and supports National Institutes of Health (NIH)-supported efforts aimed at understanding molecular mechanisms of DNA repair, cancer, cell-cell interactions, and aging.

- ***Enable scientific discovery through advanced computing.*** Major scientific discoveries have depended on the National Energy Research Scientific Computing (NERSC) Center, including the data computations that revealed that the expansion of the universe is accelerating and that the Universe is "flat." Berkeley Lab has joined with other national laboratories in partnerships with computer manufacturers to develop a new generation of computer architectures tailored to scientific applications. New architectures offer the promise of the most powerful data analysis and simulations possible, addressing DOE scientific demands including those coupled to energy security and the environment, living systems, and the origin and fate of the universe. NERSC Center can address these scientific demands with new architectures that can yield high cost-effectiveness in the 150 teraflop range.
- ***Advancing science at ultrafast scales***. Berkeley Lab has been working with the community of scientists interested in ultrafast phenomena to develop powerful scientific tools to address this area of science. Berkeley Lab has conducted the studies and preconceptual design work to define the parameters for a Linac-based Ultrafast X-ray Source that would be a powerful discovery tool for the field of ultrafast science. The prospect of high intensity, coherent, tunable, synchronized x-rays having durations in the femtosecond range may now open this regime to extremely productive investigation. Berkeley Lab with other organizations hosted a national symposium that outlined the breakthroughs possible and the instrumentation that could advance the emerging science.
- ***Operate national experimental facilities at the scientific frontier.*** The focus of this goal for national experimental facilities is to develop and maintain U.S. leadership in the physical sciences and natural sciences, with a focus on Advanced Light Source (ALS) science and facility performance. The Laboratory will continue to expand the user program at the ALS, and upgrade the facility to keep it at the cutting edge. The improvements will significantly improve beam intensity, beam current continuity, and other operating characteristics.

Berkeley Lab has a distinguished record of research that improves the energy security of the nation while reducing environmental impacts. For the Office of Civilian Radioactive Waste Management, the Laboratory has developed the coupled transport models and data that supported the President's decision to propose Yucca Mountain as the nation's nuclear waste repository. We are working with DOE's Office of Energy Efficiency and Renewable Energy to further develop the most advanced energy-efficiency and -reliability technologies, and to partner with industry. Prior successes include low-emissivity windows, high-frequency ballasts for fluorescent lamps, and efficient fixtures for compact fluorescent lamps. We continue our work with national organizations and the State of California to reduce energy demand and improve electricity-distribution reliability. We are investigating the next generation of energy-efficient technologies for carbon dioxide emissions reduction. We are working towards advancing potential long-term power production through inertial confinement fusion that would be free of greenhouse gas emissions.

The Laboratory's capabilities are being called upon to serve DOE and all the national laboratories in an integrated way. Berkeley Lab works in close partnership with Oak Ridge and other laboratories for the construction of the Spallation Neutron Source, including the successful commissioning of the first project component, the Front End. Our partnerships in High Energy and Nuclear Physics are advancing the research program at the Large Hadron Collider in Europe, the Relativistic Heavy Ion Collider at Brookhaven, and the Asymmetric B Factory at the Stanford Linear Accelerator Center. We have formed the Virtual National Laboratory in partnership with Lawrence Livermore National Laboratory and the Princeton Plasma Physics Laboratory to advance inertial fusion energy science. The efforts of the Joint Genome Institute have successfully finished the sequence of human chromosomes 5, 16, and 19, and we are moving ahead to sequence other organisms, such as microbes, that advance DOE's missions. The JGI will now transform from a single purpose to a national DNA sequencing resource. Access to this resource will enable the solution to large-scale genome sequencing tasks germane to other scientific agencies. (See Section IV, Initiatives). We are managing the Consortium for Electric Reliability Technology Solutions (CERTS), which includes three other DOE laboratories as well as a number of universities.

Research Infrastructure

To sustain the Laboratory's efforts, the nation needs to invest in the science infrastructure that underpins our discoveries and, ultimately, the security, economic prosperity, and health of our citizens. The Laboratory will fall far short of its scientific goals if the infrastructure of previous generations is relied upon for a new generation of science. These next few years are a critical turning point—either towards advancement of the natural sciences through investment, or erosion through continued reliance on Manhattan Project and Atomic Energy Commission-era facilities constructed a half-century ago.

Working with the Office of Science, we are committed to building the user infrastructure necessary for our national scientific facilities. We have allocated significant Laboratory resources to infrastructure, for example, completing the Users Mezzanine of the ALS, and extending its photon flux energy into the intermediate x-ray regime. We are working with third parties to construct a new research office building and to address the needs for a user dormitory. We must join with DOE to further address space and other infrastructure needs of the growing user base as well as other facility needs. The Molecular Foundry will be a key resource for the National Nanotechnology Initiative. In addition, the Office of Science must sustain its support for dismantling the Bevatron following its illustrious career in high-energy physics, heavy-ion nuclear physics, and nuclear medicine.

Integrity and Accountability

The public has confidence in the Office of Science stewardship for American investments in science. We are working to keep that trust through robust management that holds managers and staff accountable for results, in the full letter and spirit of the President's Management Agenda. We place high value on creativity, integrity, best business practices, and a safe and secure working environment. We take many steps to assure the security of information, and are recognized for the quality and effectiveness of our cybersecurity monitoring. Our business systems must be robust and accountable to the highest standards of public review. With DOE, we are forging strategic goals and business systems based on the Under Secretary of Energy's principles for Office of Science contracts. We seek to embody best management practices in a results-based management contract, defining the roles and responsibilities of DOE and contractor personnel, behaviors, and expectations.

To align our values and business practices, people throughout the organization developed an Operations vision for the Laboratory. Operations strategic planning would address the most promising actions towards achieving the vision: *Berkeley Lab will be the best place in the world to conduct scientific research; we will be a unified Laboratory where the full contribution of every individual is expected and recognized; we will have constructive relationships with and be trusted by our sponsors, neighbors, and collaborators.*

Success in achieving this vision will be characterized by outstanding business and information systems, leading engineering capability, and a meritorious health and safety record. Our working environment will be rich with opportunities and challenge to grow to our fullest potential. We will cultivate relationships with integrity and openness. Our partnerships will open new opportunities to serve our communities, the nation, and the world. Our metrics of progress will be well-aligned with our mission.

Twenty-First Century Workforce

Ultimately, talented and creative people are the resources that give strength to American science. Because a pipeline for sustaining the scientific and engineering workforce is essential for the nation's future, strengthened science education and research mentorship are valued elements of this plan. All divisions of the Laboratory have developed diversity plans to enhance the quality of the working environment and to aid in recruitment of a diverse workforce. We have established outreach, training, and retention programs to encourage and fully respect diversity.

The School-to-Work Program is reaching out to urban schools and colleges to bring new students to the Laboratory in planned programs that offer improved prospects for career employment. New educational partnerships with community colleges and secondary schools promise local and national benefits linked to DOE technology and scientific resources.

Berkeley Lab's institutional distinction is built on university-based scientific and management skills of our staff, and close working relationships with campuses, government, and industry. The priority needs for delivering results for the Department of Energy and fulfilling our scientific and Operations vision are reflected in this Institutional Plan.

Charles V. Shank

Director

II. LABORATORY MISSION

Berkeley Lab is a multiprogram national scientific facility operated by the University of California for the Department of Energy (DOE). As an integral element of DOE's National Laboratory System, Berkeley Lab conducts key elements of DOE's security missions in science, energy, and the environment. In support of these missions, Berkeley Lab:

- Performs leading multidisciplinary research in the computing sciences, physical sciences, energy sciences, biosciences, and general sciences in a manner that ensures employee and public safety and environmental protection.
- Develops and operates unique national experimental facilities for qualified investigators.
- Educates and trains future generations of scientists and engineers to promote national science and education goals.
- Transfers knowledge and technological innovations, and fosters productive relationships among Berkeley Lab's research programs, universities, and industry.

The Laboratory's results-based management efforts are directed towards advancing DOE overall strategic interests, and to the Office of Science goals to advance the frontiers of the physical sciences and areas of the biological, environmental, and computational sciences that deliver the scientific knowledge and discoveries for DOE's missions. The Laboratory's activities address the Department of Energy's goal to provide world-class research facilities and essential scientific human capital to the nation's overall science enterprise.

SCIENTIFIC ROLE AND LABORATORY PROFILE

Berkeley Lab is unique among the multiprogram laboratories, with its proximity to major research universities, the University of California at Berkeley (UCB) and the University of California at San Francisco (UCSF). The Laboratory's principal role for DOE is fundamental science, including developing powerful experimental and computational systems for exploring properties of matter, deepening understanding of molecular interactions and synthesis, and gaining insights into biological molecules, cells, and tissues. The Laboratory is a major contributor of research on energy resources, including efficient energy use, the earth's structure and energy reservoirs, fusion, and combustion of fuels. The Laboratory is extensively involved in environmental research, including Yucca Mountain site characterization, subsurface contaminant transport, bioremediation, and indoor air quality. User facilities include the Advanced Light Source, National Energy Research Scientific Computing Center, National Center for Electron Microscopy, 88-Inch Cyclotron, Gammasphere, and Biomedical Isotope Facility. Our multidisciplinary research environment and unique location serve to strengthen partnerships with industry, universities, and government laboratories. Partnerships include the Joint Genome Institute and programs in advanced accelerator and detector systems, x-ray lithography, high-speed networking and computer architectures, building and lighting systems, and science education. These principal, contributing, and specialized participating roles support DOE's strategic planning and are based on the core competencies described below.

Berkeley Lab complements the work at other national laboratories in several key national program areas. Its detector expertise deployed in the Solenoidal Tracker (STAR) detector successfully operating at the Relativistic Heavy Ion Collider (RHIC) complements accelerator efforts at Brookhaven National Laboratory. This is also the case for our work on the BaBar Detector now conducting charge-parity measurements in the b-meson system at the Stanford Linear Accelerator Center (SLAC). Berkeley Lab's ion-source efforts for developing the front end of the Spallation Neutron Source complement the experimental systems being developed at Oak Ridge National Laboratory, the linac work being conducted at Los Alamos National Laboratory, and the compressor-ring design and development at Brookhaven National Laboratory. Berkeley Lab's unique expertise in induction linacs also called for our complementary contributions to the Dual Axis Radiographic Hydrodynamic Test Facility. In the biosciences, Berkeley Lab's automation and genomics work complements the competencies at Los Alamos and Livermore Laboratories whose programs have come together at the Joint Genome Institute's Production Genomics Facility, which is among the most productive sequencing operations in the world.

CORE COMPETENCIES

The ability of Berkeley Lab to advance its strategic roles for DOE depends upon its "core competencies." These competencies are an integration of research disciplines, personnel, skills, technologies, and facilities that produce valuable results for our sponsors. The core competencies also enable Berkeley Lab to respond to changing national needs and new research problems.

- **Advanced Detector Systems.** Major detectors for astrophysics, high-energy physics, and nuclear science; scientific conception and project leadership; advances in particle and photon detection; implementation of new concepts in detector technology.
- **Advanced Technologies for Energy Supply and Energy Efficiency.** Building technologies; energy analysis; electrochemistry; fossil-fuel technologies; subsurface resources and processes.
- **Bioscience and Biotechnology.** Structural biology; genomics and proteomics; bioinstrumentation; biological and medical imaging; molecular, cell, and tissue biology; cancer, aging, and other human diseases; biomolecular design; environmental biology.
- **Characterization, Synthesis, and Theory of Materials.** Nanoscience and nanotechnology; advanced spectroscopies and microscopies based on photons, electrons, and scanning probes; ceramics; alloys; heterostructures; superconducting, magnetic, and atomically structured materials; biomolecular materials.
- **Chemical Dynamics, Atomic Physics, Catalysis, and Surface Science.** Reaction dynamics; photochemistry of molecules and free radicals; dynamics of atomic and molecular photoionization; surface structures and functions; heterogeneous, homogeneous, and enzymatic catalysis.
- **Computational Science and Engineering.** Computational fluid dynamics; applied mathematics; computational chemical sciences; algorithms for scalable systems; discretization algorithms for partial differential equations; distributed memory; visualization techniques; scientific data management; network research; collaborative technologies.
- **Environmental Assessment and Remediation.** Advanced instrumentation and methods for environmental characterization and monitoring; human health and ecological risk assessment; indoor air quality; subsurface remediation of contaminants; geologic isolation of high-level nuclear waste; actinide chemistry.
- **Particle and Photon Beams.** Analysis and design of accelerators; induction linacs and neutral beams for fusion energy; beam dynamics; high-brightness ion, electron, and photon sources; advanced magnet design and research and development; radiofrequency (rf) technology; x-ray optics and lithography; ion-beam sources for lithography and semi-conductor processing.

DIVISION RESPONSIBILITIES

While the core competencies underpin the Laboratory's role for DOE, to achieve DOE programmatic goals the Laboratory is managed through divisions that implement DOE and other sponsors' research programs. These divisions have line- and project-management responsibility to deliver results for DOE programs within scope, schedule, and budget, in a safe, secure, and environmentally protective manner. As indicated in the following organization chart [see Figure II (1)], the divisions are structured to serve multiprogram needs, and their strengths are summarized below. Importantly, many projects are staffed and supported through a matrix of division personnel, with computational, engineering, and technical services integrated in research teams across the physical sciences, energy sciences, biosciences, and general sciences divisions.

Computing Sciences

- **National Energy Research Scientific Computing (NERSC) Center Division**. Unsurpassed high-end computing services to the Department of Energy user community as well as a wide range of other university, government, and industry users; access to the most powerful computer for unclassified research in the United States, a 6,656-processor IBM RS/6000 SP with a peak speed of 10 teraflop/s; an archival data storage capability of 8.8 petabytes; comprehensive scientific support to enable a broad range of scientists to effectively use NERSC systems in their research; support for science-of-scale and data-intensive projects; and deployment of technology to integrate NERSC into the DOE Science Grid.
- **Computational Research Division.** Applied research and development in computer science, computational science, and applied mathematics, including system architectures, software implementation, mathematical modeling, and algorithmic design; software components that allow scientists to address complex and large-scale computing and data analysis problems in a distributed environment such as the DOE Science Grid; direct collaboration with scientists to solve computational and data management problems; and visualizations to help scientists gain new physical insights and make data more comprehensible.
- **Mathematics Department.** Development of numerical and analytical methods and their application; problems in physics and engineering; vortex and particle methods; solid mechanics and fracture; interface techniques; turbulence theory; dynamics of polymeric systems; parallel implementation of codes for large-scale scientific computing; fast algorithms.
- **Information Technologies and Services Division (ITSD).** Information technology infrastructure and services, including cybersecurity, business applications, desktop computer support, electronic mail, networking and telecommunications, and technical information. ITSD includes the Energy Sciences Network (ESnet), an international high-speed computer-data-communications network serving thousands of DOE scientists and collaborators at laboratories and universities worldwide by providing high-bandwidth, reliable connections.

Physical Sciences

- **Advanced Light Source (ALS).** Provides a growing scientific user community with high-brightness ultraviolet beams, soft x-ray and intermediate energy x-rays for scientific advancement in many fields; supporting scientists from universities, government, and industry in areas such as protein crystallography, condensed matter physics, reaction dynamics, surface science, molecular environmental sciences and biology; user services and experimental systems support; operational systems; optical and beamline systems; synchrotron physics and engineering.

- **Chemical Sciences.** Chemical physics and the dynamics of chemical reactions; structure and reactivity of transient species; synthetic chemistry; homogeneous and heterogeneous catalysis; chemistry of the actinide elements; molecular and environmental chemistry; atomic physics.
- **Materials Sciences.** Advanced ceramic, metallic, polymeric, magnetic, biological, and semi- and superconducting materials for catalytic, electronic, optical, magnetic, structural, and specialty applications; studies of nanoscience, nanodevices, and nanotechnology; development and use of instrumentation, including spectroscopies, electron microscopy, x-ray optics, nuclear magnetic resonance, and analytical tools for ultrafast processes and surface analysis.
- **Physical Biosciences.** Integrates the techniques and concepts of the physical and engineering sciences into the investigation of biological challenges requiring large-scale team research in concert with individual exploration. Emphases include macromolecular structure, function, and dynamics; rapid automated methods for gene expression optimization; biochemical reaction networks; cellular machinery engineering; high-throughput determination of protein structure and function; sensory and signaling systems; nanoscale manipulation of molecular architecture; genetics and mechanisms of photosynthesis; operation and development of the Berkeley Center for Structural Biology at the ALS and the Berkeley Structural Genomics Center.

Energy Sciences

- **Earth Sciences.** Structure, composition, and dynamics of earth's subsurface, geophysical imaging methods; chemical and physical transport in geologic systems, including carbon sequestration, isotope geochemistry; physiochemical process investigations; environmental biotechnology; climate modeling; and carbon cycle science.
- **Environmental Energy Technologies.** Energy-efficient building technologies; indoor air quality; batteries and fuel cells for electric vehicles; combustion, emissions, and air quality; industrial, transportation, and electricity reliability and energy use; national and international energy policy studies; aspects of global climate change related to energy.

Biosciences

- **Genomics.** Production sequencing for a variety of organisms including microbes; microbial communities; organisms of important scientific, economic, and technical interest; development of biology based on large genomic databases.
- **Life Sciences.** Integration of experimental and theoretical connections between genes and proteins, their function, and their organization within cells and tissues; investigation of the basic mechanisms of human disease, including the biology and genetics of breast cancer, DNA repair and genomic stability, mechanisms of aging, metabolic studies of neurological diseases; structural biology of molecular machines; health effects of low-level ionizing radiation; functional genomics and microarray technology; development of human-disease models in mice; nuclear chemistry; biological and functional imaging at molecular, cellular, and human scales.

General Sciences

- **Accelerator and Fusion Research.** Fundamental accelerator physics research; accelerator design and operation; advanced accelerator technology development for high-energy and nuclear physics; accelerator and beam physics research for heavy-ion fusion; beam and plasma tools for materials sciences, semiconductor fabrication, and engineering and biomedical applications, and for other advanced detection applications.

- **Nuclear Science.** Relativistic heavy-ion physics; low-energy nuclear physics; nuclear structure; nuclear theory; nuclear and neutrino astrophysics; weak interactions; nuclear chemistry; studies of transuranium elements; nuclear data evaluation; advanced detector development; operation of the 88-Inch Cyclotron; pre-college education programs.
- **Physics.** Experimental and theoretical particle physics; advanced detector development; astrophysics; particle database for the high energy-physics community; innovative programs for education and outreach.

Resources and Operations

- **Engineering.** Engineering design, planning, and concept development for scientific programs and projects; advanced accelerator components; electronic and mechanical instrumentation; scientific applications software development; laboratory automation; fabrication of detectors and experimental systems.
- **Environment, Health, and Safety.** Technical support for protecting the safety of employees, the public, and the environment; radiation safety associated with accelerator technology, hazards assessment, and control of radionuclides; waste management.
- **Facilities.** Architectural, engineering, construction and maintenance devices for infrastructure; property management and logistical support for Laboratory operations.
- **Resource Departments.** Administrative, financial, human resources, and technical services for research and institutional management.

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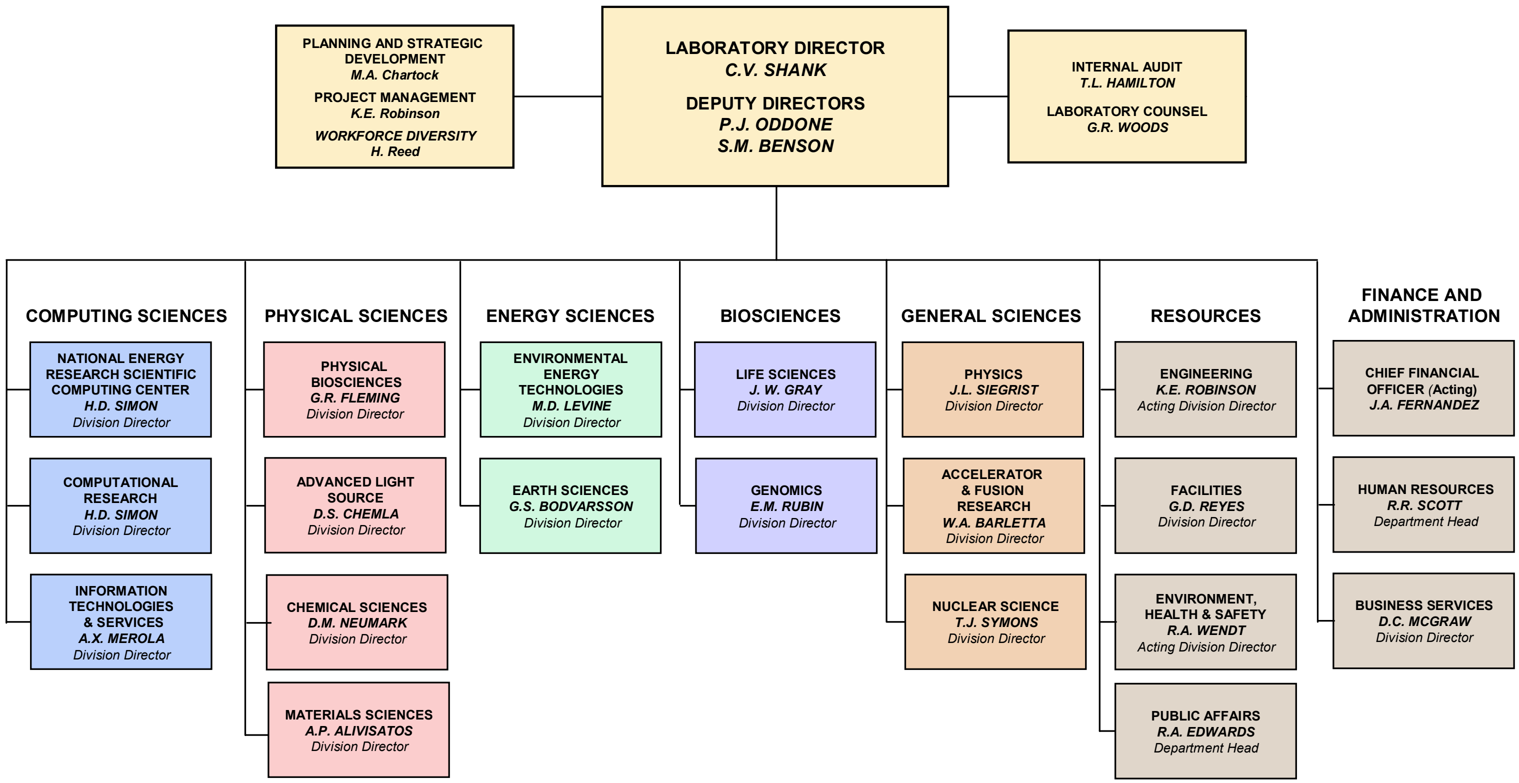

Figure II (1) Ernest Orlando Lawrence Berkeley National Laboratory Organization Chart

III. LABORATORY STRATEGIC PLAN

The Berkeley Lab Strategic Plan describes the Laboratory's Science Vision and Strategic Goals. Achieving these goals represents major advances in science, transforming our view of the world and enabling new benefits for the nation. The Plan identifies the research that supports the mission of the Office of Science and our other research sponsors. The Berkeley Lab Strategic Plan also identifies the Operations vision, and the steps being taken to strengthen business systems.

SCIENCE VISION AND GOALS

The Science Vision for Berkeley Lab is to provide scientific leadership that gains revolutionary technical knowledge to benefit the nation and the people of the world. Berkeley Lab planning focuses our resources on the most promising research activities. Our Science Strategic Goals stretch the limits of scientific capability. We desire no less than to harness the power of the living world, design a new generation of materials forged at atomic scale, discover the origins of matter and the universe, and provide powerful research facilities that make new science possible. Through computational science-of-scale, we will deliver new discoveries at extreme frontiers not possible through experimentation and theory alone. We will work with the Office of Science to refine and further Science Strategic Goals of great scope and impact. The "stretch" Science Strategic Goals and key results proposed in this plan include:

- ***Designing new generations of materials with tailored properties****, including materials systems with precise electronic, structural, and optical properties.* Berkeley Lab is constructing a Molecular Foundry to advance the Office of Science role in the National Nanotechnology Initiative. This science research center will focus on both soft and hard nanostructured building blocks and their fabrication into functional multicomponent assemblies. The Foundry is a user facility for visiting scientists, and will also maintain an internal research program, a training program for students and postdoctoral fellows, and portals to other Berkeley Lab major user facilities, including the Advanced Light Source (ALS), the National Center for Electron Microscopy (NCEM), and the National Energy Research Scientific Computing (NERSC) Center. Coupled to the nanoscience initiative is the development of a new microscope, the Transmission Electron Aberration-Corrected Microscope, which will advance NCEM's capabilities.

  By 2007 the Molecular Foundry will be constructed, ushering in a new centerpiece for collaborative nanoscience research, a national user facility dedicated to advancing materials with integrated assemblies of organic and inorganic molecular components. New nanostructured materials components will be developed from research conducted at the Molecular Foundry, including materials with unique properties and new potential designs for devices such as solar cells.

- ***Measuring the most dominant constituent of the universe—dark energy.*** Berkeley Lab is undertaking a research and planning effort for an astrophysics satellite program that will define the fundamental properties of the universe through the observation of supernovae. The effort stems from mounting supernova evidence that the expansion of the universe is accelerating, perhaps driven by an unseen dark energy. The observation of sufficient numbers of supernova events is necessary to measure the mass density, energy density, and curvature of the universe, and to address this newly discovered dark energy. The international collaboration for this satellite mission, a SuperNova/ Accelleration Probe (SNAP), will require resources for planning and experimental development during the next several years, in advance of project implementation. The mission is now in the research and development phase, with plans calling for project engineering and design starting in two years, and launch in 2010.

During the period of the Institutional Plan, the SNAP program will focus on developing a conceptual design, the beginning of engineering design, and fabrication and testing of prototypes for the principal SNAP instruments. The research program focus supports the High Energy Physics Advisory Panel and the National Research Council report, *Quarks to the Cosmos*, which identified this interdisciplinary research area as a high priority for an interagency initiative. Before the end of the planning period, SNAP will move from the research and development phase to a project status with emphasis on engineering design and approval of project milestones. Following the launch in 2010, subsequent data gathering for dark energy characterization and results published by mid-decade will bring about a new era of precision cosmology and reveal precise measurements of dark energy and the equation of state of the universe.

- ***Understanding the machinery of cells at the most fundamental levels through advanced computational and scientific tools.*** In the era that follows the sequencing of the human genome, a new biology program for the Office of Science is directed at developing a more predictive and quantitative understanding and control of microbiological systems. This includes characterizing the regulatory networks of microorganisms and creating data-driven, validated models of biological responses in environments of critical importance to DOE. Berkeley Lab's efforts are directed towards an integrated program of environmental microbiology, functional genomic measurement, and computational analysis and modeling to understand the basic biology of microbial systems and to restore contaminated environments.

  The Berkeley Lab Genomes for Energy and the Environment: Genomes to Life effort is working to establish high throughput protein complex characterization, functional genomics and metabolomics, and computational facilities as productive user facilities and use them to build and test accurate predictive cell models of regulatory networks response to stress. To better understand and engineer microbial systems and restore contaminated sites, advanced computational models of the organisms will be developed that show good agreement with observations.

- ***Advancing science at ultrafast scales.*** Phenomena taken for granted in everyday life have roots in an ultrafast time regime. Energy production, photosynthesis, air pollution, and processes of living and nonliving systems all result from events taking place in the femtosecond time scale. Until recently, studies with high-intensity probes in this regime have been beyond the reach of science. Berkeley Lab and the Stanford Linear Accelerator Center recently hosted a well-attended national symposium that outlined the breakthroughs possible and the instrumentation that could advance the emerging science.

  Berkeley Lab has conducted the studies and preconceptual design for a Linac-based Ultrafast X-ray Source (LUX) that would be a powerful discovery tool for the field of ultrafast science. The prospect of high-intensity, coherent, tunable, synchronized x-rays having durations in the 50-femtosecond range may now open this regime to extremely productive investigation. Over the near term, Berkeley Lab has successfully demonstrated the time-slicing method for producing femtosecond scale x-rays from bend magnets at the ALS. Progress is being achieved in developing a higher brightness slicing source with a narrowgap undulator at the ALS.

  LUX would provide high flux vacuum ultraviolet (VUV) and x-rays from 20 eV to 12 keV, in pulses as short as 20 femtoseconds in the initial configuration. The Laboratory will continue to work with the national community for ultrafast science and conduct the research and development needed to further advance facility design. A national user facility with characteristics of LUX will be complementary to other x-ray sources and provide dramatic advances in ultrafast science.

- ***Enable scientific discovery through advanced computing***. The National Energy Research Scientific Computing (NERSC) Center provides high-performance computational resources that are highly valued by its DOE user community. Major scientific advancements have depended on the NERSC Center, including improved simulations of climate, fusion, and materials performance, and the data computations that revealed that the expansion of the universe is accelerating. In FY 2003 the NERSC Division plans to deliver 82 million Massively Parallel Processor (MPP) hours to its user community, with an increase to 100 million MPP hours in FY 2004. NERSC Center and the Computational Research Division also emphasize comprehensive scientific support, leveraging the Office of Science initiative on Scientific Discovery through Advanced Computing, and providing a unified environment that integrates computing with experimental science.

  NERSC Center joined with other laboratories in partnerships with computer manufacturers to develop a new generation of computing architectures tailored to scientific applications. These new architectures offer the promise of the most powerful data analysis and simulations possible, addressing DOE scientific demands including those coupled to energy security and the environment, living systems, and the properties of matter and energy in the universe. NERSC Center can address these scientific demands with new architectures that can yield high cost-effectiveness with peak performance in the 150 teraflop range and with high memory capabilities. This will make possible an advanced level of precision simulation models and data analysis for the high-performance computational science community..

- ***Operate national experimental facilities at the scientific frontier***. The focus of this goal for national experimental facilities is to develop and maintain U.S. leadership in the physical sciences and natural sciences, with a focus on ALS science and facility performance. The Laboratory will continue to expand the user program at the ALS, and upgrade the facility to keep it at the cutting edge. The improvements will significantly improve beam intensity, beam current continuity, and other operating characteristics. The goal supports the objectives of the Office of Basic Energy Sciences to develop and operate forefront scientific user facilities to achieve great accessibility for users and high scientific impact.

  This year the ALS is completing the construction of three new beamlines, expanding the end station hours delivered to users by five percent over last year, and fully commissioning the Molecular Environmental Sciences beamline. In subsequent years beamlines and end station hours will continue to grow steadily. Next year for example, new structural biology beamlines will be commissioned. Facilities improvements are planned to include a new “top-off mode” that provides continuous high current operation. At least 40 beamlines are expected to be in operation during the coming several years, serving the growing user community and delivering important advances for nanoscience, environmental, and energy research. Realizing the ALS Science Strategic Plan will greatly benefit the growing ALS user community.

Three energy issues complement Berkeley Lab’s Science Vision: How can the nation provide secure and reliable supplies of electricity and other forms of energy? How might technology be applied to reduce the public’s energy consumption in support of DOE’s goals to modernize energy conservation? What are the long-term global consequences of energy use, and how can potential problems be mitigated? Berkeley Lab has been a leader in the areas of energy and the environment. Consumer products and energy-efficiency analysis tools developed here have saved billions of dollars in annual energy costs. For two decades, the Laboratory has pursued the concept of heavy-ion fusion, increasingly viewed as a practical possibility in the effort to harness fusion energy. The Laboratory stands ready to develop a design for an Integrated Beam Experiment (IBX) to further advance the scientific understanding of beams and plasmas, and the engineering issues of heavy-ion inertial fusion. In the coming years, we also plan to advance the nation’s understanding of carbon sequestration to mitigate the potential effects of global greenhouse gases.

OPERATIONS STRATEGIC DIRECTION

A key management direction is to sustain high levels of scientific productivity and business accountability now and for the future. As indicated below, achieving Berkeley Lab's Science Vision and delivering results is also a part of the Operations strategic planning effort, to provide support for science that is effective, efficient, and safe. The Operations planning activities have been an outgrowth of the Best Practices Pilot Study (below) and efforts directed to four goal areas: (1) Integrating best business practices to provide efficient and effective operational support to the science missions of the Laboratory; (2) Improve facilities and our engineering and information technology systems to support the current and future programs of the Laboratory; (3) Improve employee development and effectiveness while creating a motivating work environment that attracts and retain high-caliber employees; and (4) Build constructive and supportive relationships with constituent groups improve the understanding of the Laboratory within the community. Some key areas of operations activities include:

- **Best Operational and Administrative Practices**. Berkeley Lab is committed to improving management efficiencies, eliminating redundancy, and focusing on results. The Best Practices Pilot Study, conducted at the request of DOE leadership, identifies principles for efficiently and effectively administering and operating a scientific laboratory. These practices contributed to DOE's development of principles for science laboratory contracts. Berkeley Lab is focused on pre-contractual discussions with DOE and the UC Office of the President to frame a results-based DOE-UC Contract and management relationships anchored in Best Practices principles. A results-based contract and well-defined management relationships offer the prospect of effectively and efficiently delivering on the goals of the Office of Science, DOE, and the Administration. The effort directly supports the new results-based policies of DOE and the Office of Management and Budget, the President's Management Agenda, and the Government Performance and Results Act of 1993.
- **Accountability**. Through line management accountability, Berkeley staff develop and execute their work with integrity, efficiency, and effectiveness. The executive managers are held accountable by DOE for what takes place at Berkeley Lab. Senior managers work to create and maintain an atmosphere that fosters a culture of accountability and integrity. The Laboratory's annual evaluations performed by DOE have been "outstanding." Nonetheless, we have taken concrete steps to further enhance business systems for greater accountability. This includes improvements in purchasing and receiving systems. For example we have dramatically reduced the number of purchasing cards, increased training and improved accountability at all levels. Employees who find potential problems are encouraged to come forward and share that information with supervisors or senior managers with the assurance that reporting will not result in recrimination of any kind.
- **Research Infrastructure.** Berkeley Lab's facilities planning advances DOE's science program goals through modernizing and constructing facilities while maintaining high standards of performance in safety and protection of the environment. Critical elements of Berkeley Lab's planning are adequate space and facilities for users at the Laboratory's national user facilities in order to meet program goals for the 21st century, and modernization through program line-item projects and the Science Laboratory Infrastructure program. Because facilities planning is a critical element of the Laboratory's stewardship activities, it is included as Section VI of this Institutional Plan, and provides an integrated framework and priority structure for the Laboratory's infrastructure needs.
- **Effective Project Management.** Berkeley Lab is committed to outstanding project management and has a strong record of projects being delivered on scope, budget, and schedule, including, for example, the Front End for the Spallation Neutron Source. Nevertheless, to assure continued performance, the Laboratory has established an Integrated Project Management Office that coordinates senior management reviews to assure high performance and a continued reputation as

location-of-choice for major science projects. An Integrated Project Management Board reviews projects at early stages of development.

- **Integrated Safety Management (ISM).** Berkeley Lab policy is to integrate its performance in the areas of environment, safety, and health into the planning and implementation of all of its operations, in order to protect the health of employees, the public, and the environment. Laboratory plans integrate environment, safety, and health requirements in a prioritized manner to assure that Berkeley Lab can meet DOE's Critical Success Factors for these areas in the conduct of research. Berkeley Lab has been among the first laboratories to fully implement its ISM, which has recently been validated.
- **Effective Community Relationships**. Berkeley Lab has established a Public Affairs organization that fosters constructive relationships with the community and engages in proactive corporate citizenship activities. These activities include mechanisms to incorporate community concerns into decision making and the establishment of effective lines of communications and trust. Berkeley Lab has worked with the City of Berkeley on the development and implementation of its community-based vegetation management plan; serves in a leadership position in the Berkeley Hills Emergency Forum; maintains a partnership with the City for first response by the Laboratory's Fire Department; and—with DOE Oakland—is a participant in the mutiagency Partnership for Parks.
- **Workforce Diversity and Recruitment.** Enhancing the diversity of our workforce is a vital part of our collective strength and success as a Laboratory. We are committed to building a community in which diversity is valued, cultural differences are respected and even celebrated, and individuals perceive fairness and equity across the board. The Laboratory's new results-oriented Diversity Plans reflect this commitment. They are division-specific and provide strategies and actions to enhance the work environment for all employees, and methods of outreach and recruitment to promote equality of opportunity. Employees are encouraged to view these plans and participate in their own group's workforce diversity program. The Laboratory is working to improve minority recruitment in key areas through targeted outreach efforts and a long-term School-to-Work program. The Laboratory is working at all levels, including its senior and mid-level managers and its entire workforce — with efforts that include the Division Diversity Plans — to improve the recruitment and retention of a diverse workforce.
- **Integrated Safeguards and Security Management (ISSM).** Berkeley Lab has developed effective Site Security and Cyber Security Program Plans that protect our employees, visitors, equipment, facilities, and information. The Plans are tailored to the risks at the site and provide for full security protections while enabling the Laboratory to conduct its unclassified research mission as a Tier III laboratory (no classified research or information on-site). An Integrated Safeguards and Security program was established in 2001. The maturing ISSM program is used to heighten employees' security awareness and provide feedback to senior management.

DELIVERING RESULTS FOR DOE PROGRAMS AND OTHER SPONSORS

Within the fabric of American science, Berkeley Lab serves as a multiprogram science laboratory whose primary focus is fundamental science with important contributions in energy security and environmental research. Berkeley Lab's long-term strategy is to serve as a results-based scientific organization that delivers on the quality, relevance, and performance goals of the sponsoring DOE program offices. The following discussion presents a synopsis of Berkeley Lab's efforts for our major Laboratory research sponsor — the Office of Science — and for other DOE Offices, government agencies, and other sponsors.

Office of Science

The Office of Science is the primary customer for Berkeley Lab's fundamental science mission. The Office of Science is the third-largest government sponsor of basic research in the United States and the largest government supporter of the physical sciences. Berkeley Lab's research and facilities support, in particular, the following research offices: Advanced Scientific and Computing Research, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, and High Energy and Nuclear Physics. The level of funding provided by these offices is indicated in Section VIII, Resource Projections and Tables.

Office of Advanced Scientific Computing Research

Berkeley Lab plays a key role in developing and deploying the computational and networking tools used by the DOE research community. The Laboratory manages and operates the Office of Science's two national computing and networking facilities, the National Energy Research Scientific Computing (NERSC) Center and the Energy Sciences Network (ESnet). NERSC is the flagship general-purpose, high-end computing facility for the Office of Science, providing 10 teraflops of computing capability and 8.8 petabytes of storage to more than 2,000 scientists nationwide. NERSC Center provides comprehensive scientific support for users and special support for teams collaborating on science-of-scale and data-intensive projects. NERSC also deploys grid technology to connect its computing and storage systems to the DOE Science Grid. The Energy Sciences Network (ESnet) is the backbone of DOE's research network, providing access to NERSC Center and to other research, experimental, and computational facilities for scientists across the nation as well as international collaborators. ESnet recently completed a bandwidth upgrade to 2.5 gigabits per second, with 10 gigabits per second in the highest-speed portion of the network.

In applied mathematics research, Berkeley Lab mathematicians seek the underlying mathematical understanding and develop the numerical algorithms that enable effective description and prediction of physical systems. Laboratory mathematicians are leaders in the development of adaptive mesh refinement (AMR) techniques, which allow different spatial and temporal resolution in different regions of a model, enabling the solution of larger, more complex computational problems. Berkeley Lab's open-source AMR software is unique among many AMR codes because of its adaptability to a wide range of applications and its high performance across multiple platforms. Other areas of mathematics research include level set methods and fast marching methods, which are numerical techniques for analyzing and computing interface motion in a host of settings; developing high-performance algorithms and software for solving partial differential equations; numerical linear algebra techniques, such as dense and sparse linear and eigen system solvers; algorithms for computer vision research; and experimental mathematics. Applications of Berkeley Lab mathematics research include physics and astrophysics, chemistry, fluid dynamics, combustion, fusion energy, materials science and nanoscience, seismology, accelerator design, medical imaging, and robotics.

Computer science research at Berkeley Lab includes evaluation and testing of new computer architectures and storage systems; performance analysis of scientific applications on terascale systems; development and implementation of scalable systems software, utilities, and programming languages on various architectures; and development of a coordinated framework for the unification, development, deployment, and reuse of scientific data management software. Berkeley Lab research in scientific visualization aims to keep pace with advances in computer science, software engineering, data modeling, and data management; projects include an open visualization framework for high performance, remote and distributed visualization, as well as methods for direct volume rendering of AMR data. Computational scientists at the Laboratory collaborate with researchers in the physical and life sciences to develop new and improved computational approaches to scientific problems, in areas such as astrophysics, global climate modeling, materials sciences, genomics, and high-energy and nuclear physics.

Berkeley Lab's research and development of collaboration and networking technologies is focused on creating an integrated science environment, combining experiment, simulation, and theory by facilitating access to computing and data resources as well as large DOE experimental instruments; areas of R&D include collaboration technologies, data-intensive distributed computing, secure Grid technologies, and advanced network technologies.

For the Office of Science's Scientific Discovery through Advanced Computing (SciDAC) program, Berkeley Lab is the lead organization for the Applied Partial Differential Equations Center, the DOE Science Grid, the Performance Evaluation Research Center, and the Scientific Data Management Center; the Laboratory also shares leadership of the Advanced Methods for Electronic Structure project and the Advanced Computing for 21st Century Accelerator Science and Technology project. In addition, Berkeley Lab researchers collaborate on the following SciDAC projects: Earth Systems Grid, National Fusion Grid, Particle Physics Data Grid, Scalable Systems Software Center, Terascale Community Climate System Model, and Terascale Optimal Partial Differential Equation Solvers (TOPS) Center.

The Office of Advanced Scientific Computing Research also manages Technology Research programs, to which Berkeley Lab has made important scientific contributions. Examples include novel applications of positron emission tomography (PET) imaging for evaluating genetic treatment of Parkinson's disease and a new photoelectron emission microscope at the Advanced Light Source (ALS) for studying micromagnetic structures.

Office of Basic Energy Sciences

Basic Energy Sciences programs focus on advanced materials and nanoscience, physical chemistry, and geosciences. The DOE Materials Sciences Program supports the ALS, which provides the world's brightest beams of ultraviolet and soft x-ray radiation and, with new superbend magnets, is now a powerful source of harder x-rays for structural studies. The ALS has substantially increased the delivery of beamline-hours and its science user base over the past year, with 1,600 users in FY 2003. The National Center for Electron Microscopy is also a powerful user facility for the Basic Energy Sciences program. Berkeley Lab research addresses solid-state physics, surface sciences, catalysis, polymers, biomolecular materials, metallurgy, electrochemical materials, electronic materials (including super- and semiconductors), ceramics, and materials chemistry. A core capability is in the area of nanotechnology building blocks and assemblies of both soft- (e.g., carbon) and hard- (e.g., silicon) based nanomaterials. The Molecular Foundry, a proposed user facility, is now proceeding with conceptual design leading towards authorization for Title I detailed design. The Laboratory delivered on its commitments to the multilab partnership for building the Front End of the Spallation Neutron Source, with the final commissioning of the Front End at Oak Ridge in December 2002.

Berkeley Lab continues to expand its programs in biological studies using synchrotron radiation. Six protein crystallography beamlines are in operation at the ALS. Two additional beamlines are expected to be operational by late summer, including a state-of-the-art experimental beamline using Small Angle X-Ray Scattering (SAXS). Technology development to advance automation and remote access continues to be a priority. Our long-range technical development goal for structural biology at the ALS is to achieve maximum automation of tasks currently carried out manually when performing diffraction experiments on synchrotron beamlines. These initiatives will generate a combination of hardware and software at the Advanced Light Source that will significantly increase user productivity and improve the quality of data collected. The tools and methods will help keep ALS at the forefront of synchrotron productivity, and also be of benefit to other synchrotron sites worldwide. For details on these activities, please refer to "Work for Others General Trends" below.

Berkeley Lab supports DOE's Chemical Sciences Program in the areas of catalysis, chemical physics, dynamics and mechanisms of chemical reactions and combustion processes, actinide chemistry, and atomic physics. A range of studies are conducted, including electron spectroscopy, laser-material interactions, photochemistry, theoretical chemistry, actinide studies germane to environmental issues, and electrochemical processes and systems. In support of the DOE challenge to predict and control chemical reactivity, Berkeley Lab has a special focus on fundamental studies of chemical reaction dynamics ranging from laser-based coherent control schemes to the development of first-principles understanding of homogeneous and heterogeneous catalysis. These investigations are greatly facilitated by the Chemical Dynamics Beamline at the ALS, and the Laboratory is expanding this program and related studies in dynamics of molecular and atomic processes with new scientific staff and renovated laboratories. The Molecular Environmental Sciences beamline, which will advance the fundamental understanding of the complex interactions of contaminants with their environment at the molecular level, began operations in the Fall of 2002. In support of the Catalysis Science research program, Berkeley Lab is proposing to advance the understanding of mechanisms of biological catalysis to advance synthetic catalysts. The proposed program will bring together expertise in biological catalysis, homogeneous and heterogeneous catalysis, synthetic chemistry, and computational chemistry with the aim of developing new approaches to synthetic catalysts built upon an understanding of biological catalysts. The results of this effort will contribute to the predictive design and synthesis of novel catalysts that can be used in the chemicals and pharmaceuticals industries.

DOE's Geosciences Program at Berkeley Lab is strengthening its multidisciplinary effort to establish the scientific basis of many technologies related to energy and the environment. This effort includes fundamental studies related to the development of hydrocarbon resources, remediation of toxic waste sites, safe disposal of radioactive and toxic chemical wastes, and mitigation and sequestration of carbon dioxide emissions. A new thrust in this area is an environmental nanoscience research program to conduct laboratory experiments and numerical simulations to learn how nanosized materials, such as iron oxides and zinc sulfate, grow and aggregate into larger crystalline forms under inorganic and unusual organic conditions. Earth sciences researchers at Berkeley Lab are also among the leading experts in the areas of subsurface imaging of the structure and dynamics of the earth's crust, experimental investigation of the mechanisms by which lithospheric processes influence energy resources, and numerical modeling of geochemical and hydromechanical processes occurring in heterogeneous fractured rock formations.

For Energy Biosciences, Berkeley Lab's program continues to improve understanding of the unique features of photosynthetic organisms for collecting light and storing it as chemical energy. It also pursues the conjunction of biology and materials science in the biomolecular materials program. New directions in research in photosynthesis cut across specialties to address two major scientific issues: the delineation and application of nature's design rules to create new functions in photosynthesis, and the obstacles toward progress in the harnessing of sunlight and its conversion to alternative fuels. This integrates expertise in synthesis, genetics, and dynamics to elucidate mechanisms and design principles from natural antenna systems, and applies this knowledge to the creation of engineered synthetic assemblies. To investigate the control and function that is the hallmark of the living state, Berkeley Lab scientists are planning to build simplified systems that mimic a number of functions of the living cell, and are amenable to monitoring and external control. These systems, called "biobots," will operate as *cell automata* capable of performing a few coordinated functions. Biobots will be ideal test beds for the study of self-assembly, signal transduction, and molecular machines, and they will also be vital to develop, test, and refine computer models of dynamic cellular processes.

Office of Biological and Environmental Research

Research at DOE's Joint Genome Institute (JGI) successfully delivered on the national goal of a final human genome sequence; has completed the draft sequence of the puffer fish for comparative genomics; and has sequenced many key bacterial genomes. Analysis of the biologically relevant signals culled from sequence information is under way. The biological function of the human DNA sequences will be determined using transgenic mice developed by researchers at Berkeley Lab, and by comparisons with other organisms. Related programs include studies in gene expression within mammary-gland and blood-forming systems, and hematopoietic research.

Research by the DOE's JGI successfully delivered on the national goal of finished sequence for three assigned human chromosomes: 13, 16, and 19. The JGI has completed the draft sequence for pufferfish for comparative genomics, and the sequence of *Ciona intestinalis* for deciphering evolutionary-based vertebrates, and has made significant progress sequencing the genome of the poplar. Analysis of the relevant biological signals coming from sequence information is underway and includes efforts of the various animal, plant, and microbial species as well as deciphering the genome of humans. The biological function of human DNA sequences are being determined in combination with the work going on at JGI as well as collaboration with genome researchers at Berkeley Lab.

The JGI has increased its production rate to greater than 1.6 billion bases per month. This dramatic progress has accelerated the sequencing of multiple microbes, and model organisms genome sequences, offering opportunities to decipher sequences coding proteins and noncoding elements involved in the regulatory circuitry of animals. Now that the JGI has become one of the largest and most efficient multimegabase sequencing centers in world, many genomes from functionally important microbes, including those important to DOE missions in energy and environment and those connected to the DOE Genomes for Energy and the Environment: Genomes to Life program, are being addressed. This has also turned the JGI into a facility providing a special need for sequencing beyond that connected with the human genome program. This has included sequencing partnerships with the U.S. Department of Agriculture and the Environmental Protection Agency (EPA). Connected with the generation of significant enormous genomic data sets, the JGI is partnering with informatics at Berkeley Lab as well as creating its own program in analysis and storage of large genomic data sets. Leveraging this production capacity as well as its informatics capacity, the JGI seeks to integrate cross species comparisons of noncoding regulatory circuitry and microbial physiology that will also develop and expand areas of computational genomics.

The research focus of Berkeley Lab's Physical Biosciences Division (PBD) is to use the techniques and concepts of the physical sciences to determine the structure and function of biologically important molecules and complexes. The program spearheads a multidisciplinary approach to science, integrating structural biology, biological dynamics, computational and theoretical biology, advanced microscopies, chemical biology, and molecular design.

In response to the explosion of synchrotron-based biological research, the Laboratory recently created a consortium to coordinate protein crystallographic and spectroscopic research at the ALS. The Berkeley Center for Structural Biology (BCSB) has a range of capabilities, including the Macromolecular Crystallography Facility and BioSpec. The BCSB is a national resource for the study and advancement of protein crystallography, and its facilities and management have made the ALS fully competitive with protein crystallography facilities worldwide. BioSpec recently became fully operational as a biological spectroscopy facility. BioSpec uses x-ray spectroscopy and other spectroscopic tools to probe the structure and mechanisms of metal-containing enzymes.

In another area of focus, multidisciplinary efforts combining the strengths of PBD and the Life Sciences Division (LSD) are being brought to bear on understanding the complex molecular assemblies or central units consisting of numerous interacting components that behave as small, self-contained molecular machines and that carry out the central functions of the cell. Research efforts at Berkeley Lab aim to employ innovative microscopies to characterize the structural dynamics of molecular machines, the cell-cell interactions, and the tissue context. Single particle cryo-electron microscopy, atomic force microscopy, optical tweezers microscopy, and single-molecule fluorescence microscopy are the selected methodologies for studies at the molecular level. They are being applied synergistically with x-ray crystallographic and small angle x-ray scattering studies to coordinate structural information with ongoing functional studies using molecular cell biology and biochemical approaches to understand the molecular machines responsible for maintaining the integrity of the genome. At the cell and tissue level Berkeley Lab's specific expertise in electron microscope tomography, soft x-ray imaging and tomography, and a variety of fluorescence optical sectioning microscopies such as two-photon, deconvolution, and confocal microscopy will be employed. Together and coupled with advances in computational image analysis, these techniques span a range of spatial and temporal resolution that will provide a uniquely detailed description of the DNA repair processes, the study of the dynamics of tissue formation and the reversion of the malignant phenotype, the effects of low-dose ionizing radiation, and the characterization of gene regulatory networks.

Research in nuclear medicine includes new studies in molecular biology, and continuing studies of improved radiopharmaceuticals and advanced instrumentation for applications to medical science. The Department of Functional Imaging in the Life Sciences Division at Berkeley Lab is involved in developing advanced positron emission tomography (PET), single photon emission computed tomography (SPECT), and nuclear magnetic resonance imaging (MRI) systems with capabilities beyond those currently envisioned for commercial implementation. This effort includes a systematic search for new, ultrafast, heavy-atom scintillators; and the development of solid-state photodetectors for high-resolution, positron emission tomography has led to new concepts in detection. The purpose of this research is to apply new technologies to the study of atherosclerosis, heart disease, aging, neurological and psychiatric diseases, and cancer.

Recent experimental measurements and computational modeling of scintillation mechanisms have lead to the discovery of a new class of inorganic scintillators able to detect gamma rays with the efficiency and energy resolution of the best scintillators but with a hundred-fold improvement in response time. When developed, these new inorganic scintillators will allow major advances in instrumentation for a variety of fields (nuclear medicine, nuclear physics, high energy physics, and astrophysics). Of particular interest in nuclear medicine is the development of a low-cost positron emission tomograph able to use time-of-flight information to reconstruct the distribution of tracer molecules in the human head with a two-fold improvement in spatial resolution and a four-fold improvement in sensitivity over conventional PET.

Berkeley Lab is engaged in several other areas related to the Office of Biological and Environmental Research mission. These include research programs in cell, molecular, and radiation biology related to cancer etiology: control of growth, differentiation, and genomic stability; hormones and extracellular matrix; mammary biology; oncogenes and tumor suppressor genes; radiation and chemical carcinogenesis; and DNA repair. Further studies entail interspecies extrapolation and risk assessment in carcinogenesis; quantitative three-dimensional image analysis; interactions of genome and cellular microenvironment; protein annotation using machine learning methods; and structural genomics.

To understand the health effects of radiation exposure, Berkeley Lab is positioned to expand the initiative in low-dose radiation based on the expertise in complex human cell culture models, fundamental knowledge of DNA repair machines, and imaging of tissue-wide response to damage. A major goal of the program is to test the validity of extrapolation of biological effect from high dose and acute exposures to low and chronic exposures that are of concern for humans' occupational and environmental exposure. Analyzing such cellular events influenced by cell-cell interactions, and signaling from distant events can also take advantage of Berkeley Lab's unique radiation sources. Transgenic animal models using novel reporter genes to identify and study critical, low-frequency responses can be coupled with new technology for *in-situ* and *in-vivo* imaging. Berkeley Lab could make significant contributions by using computational methods for integrating analyses of genomic, proteomic, and phenomic data that will form the basis of new approaches to identify pathways of cellular response and the properties of the multicellular (i.e., systemic) response. This systems biology approach stands in contrast to the recent past where research emphasis on single cell responses supported the linear no-threshold view of radiation carcinogenesis.

The Earth Sciences Division of Berkeley Lab coordinates a program office for the Natural and Accelerated Bioremediation Research (NABIR) Program Office for the Office of Science. This long-term research program, conducted by performers throughout the DOE system, focuses on basic research concerning the natural and enhanced remediation of metals and radionuclides using biological methods, e.g., immobilization *in situ*. The research on ocean carbon sequestration includes the assessment of the effectiveness and consequences of ocean fertilization and carbon dioxide injection. The research is fundamental to the feasibility, effectiveness, and environmental acceptability of ocean carbon sequestration. The effort includes a combination of *in-situ* experimentation and observations in key oceanic regimes and through numerical simulation of the ocean carbon system.

The Earth Science Division also conducts research to understand climate change and develop carbon sequestration strategies. Berkeley Lab has implemented a coordinated suite of atmospheric carbon measurements in the Southern Great Plains, as part of the DOE Atmospheric Radiation Measurement Program (ARM). Observations from crop fields, towers, and aircraft are being integrated with coupled climate-land surface models to help meet North American Carbon Program goals for carbon budget and carbon management and contribute to the AmeriFlux network. As part of this effort, the facility has been selected as a validation site for the NASA Orbiting Carbon Observatory.

Berkeley Lab research is fundamental to understanding the feasibility, effectiveness, and environmental acceptability of carbon sequestration in soil, ocean, and geologic reservoirs. The terrestrial research employs isotopic techniques to study the mechanisms governing rates of sequestration of atmospheric CO_2 in soils. Further belowground, earth science research addresses the challenges of geologic CO_2 sequestration with field studies and numerical simulations to evaluate the technical and economic feasibility of several sequestration options. To study the rapid cycling of carbon in oceans, earth scientists have developed autonomous floats that report carbon observations via satellite telemetry from remote locations. They are producing valuable data in tests of iron fertilization and fundamental research on controls of the oceans biological pump for carbon.

Earth Sciences' hydroclimate research employs state-of-the-art climate models (some running at NERSC) and statistical scaling approaches to simulate the effects of climate variability on flooding and water resources. The group recently led a multi-laboratory effort to improve regional water cycle budgeting. Continuing work is underway to incorporate isotopic tracers of the water cycle into climate models. The tracers will increase our ability to develop, test, and scale process-level representations of precipitation processes, which are one of the most important weaknesses of current general circulation models of global climate.

The Environmental Energy Technologies Division continues research on atmospheric aerosols and their implications for climate. In another climate-related effort, studies are underway on changes to land use and forestry. The goal of these studies is to illustrate the potential for carbon sequestration and emissions reduction for different types of mitigation options—by country and globally.

Berkeley Lab computational scientists are collaborating with a multi-institutional team to merge two of the world's most advanced computer climate models, the Climate System Model (CSM) and the Parallel Climate Model (PCM). The merged Community Climate System Model (CCSM) is being designed to include the best features of both models and to perform well on a variety of computer architectures.

Office of Fusion Energy Sciences

Fusion energy research at Berkeley Lab focuses on accelerator systems that support the nation's inertial-confinement energy science programs. Berkeley Lab's heavy-ion fusion accelerator research addresses the physics of the production, acceleration, compression, and focusing of intense heavy-ion beams, for their use as drivers for inertial-confinement fusion systems. Three experiments currently underway are studying new sources and initial acceleration of such beams, accelerator transport limits, and the complicated neutralization and focusing of the beams. Success in this work will allow the design of the Integrated Beam Experiment (IBX), which will conduct a wide range of experiments on beam dynamics, modeling a driver system. Expertise in induction linacs has been instrumental to Berkeley Lab's ability to deliver an advanced induction electron linac for the Dual Axis Radiographic Hydrodynamic Test Facility at Los Alamos National Laboratory, an effort sponsored by Defense Programs, which takes advantage of developments originating in the fusion energy science program. The work also includes studies of plasma heating by various methods, and support for networking and computing for fusion energy science.

Office of High Energy and Nuclear Physics

In high-energy physics, Berkeley Lab continues its strong program of experimental and theoretical research, including the development and operation of innovative detectors and research on advanced accelerator components and concepts. Berkeley Lab's experimental programs in high-energy physics focus on the properties of quarks and leptons and are closely aligned with national priorities set by the High Energy Physics Advisory Panel (HEPAP) subpanel on long-range planning. Efforts to study these particles emphasize the development of sophisticated detectors and their operation at colliding-beam facilities.

The Large Hadron Collider at CERN will search for the mechanism of electroweak symmetry breaking, and substantially extend the search for new particles beyond those described by the standard model of particle physics. Berkeley Lab is responsible for aspects of the Large Hadron Collider accelerator design and some components, as well as components for ATLAS, one of the two large experiments at the Large Hadron Collider. Berkeley Lab will play important roles in computing, the silicon tracker, and pixel detector arrays.

The Berkeley Lab-fabricated Low-Energy Ring at the B Factory at Stanford Linear Accelerator Center is operating effectively, and the Laboratory has made essential contributions to the BaBar Detector, where all components are performing well. The experiments have successfully observed charge-parity violation in the B-meson system, and further physics analysis is underway.

The Collider Detector Facility at Fermilab (FNAL) has been greatly enhanced by the Silicon Vertex Detector, for which Berkeley Lab was the lead institution. This detector played a crucial role in the Collider Detector Facility's discovery of the top quark. Berkeley Lab groups working on this experiment are involved in analysis of B decays and the measurement of the W mass and top quark masses. The D-Zero Detector at Fermilab has made important measurements of trigauge couplings and analysis of W and Z events. The Berkeley Lab group is making an essential contribution to the Run II Upgrade through work on the tracking systems and offline software, and has led commissioning activities at FNAL.

The Laboratory conducts an advanced program in astrophysics that is directed toward understanding the origins and fate of matter and energy in the universe. Key areas address supernova cosmology, cosmic background radiation, and neutrino studies. The Laboratory is working with DOE and the National Aeronautics and Space Administration (NASA) to develop a SuperNova/Acceleration Probe satellite to define the fundamental parameters of the universe, including the possible "dark energy," (see "Science Vision," above, and Section IV, Initiatives).

The Accelerator and Fusion Research Division conducts a program in accelerator research that addresses the challenges of very high field magnet designs and fabrication. Berkeley Lab leads a national program in superconducting materials development. Advanced investigations include optical accelerator and muon collider/neutrino factory research and development.

Nuclear science research at Berkeley Lab will continue to focus on the experimental and theoretical study of nuclear properties under extreme conditions. Scientists also pursue the new physics horizons recently opened in neutrino properties, and use nuclei as a quantal system to test fundamental symmetries and to understand the weak interaction. Berkeley Lab research programs are closely coupled with national priorities as defined in the DOE/NSF 2002 Long-Range Plan for Nuclear Science. Ongoing technology development efforts contribute to significant advances in nuclear instrumentation that allow progress in cutting-edge science. Large-scale computing capability is being developed at Berkeley Lab for both high-energy and nuclear-physics experiments in order to provide new concepts for data analysis, data management tools, and event simulation and distribution over networks. All of these activities are focused on maintaining Berkeley's traditional role in world-class nuclear physics.

Solenoidal Tracker at RHIC (STAR), a large acceptance, time projection chamber (TPC)-based detector for heavy-ion collisions, is in its third year of very successful data-taking at RHIC. Berkeley Lab is the lead laboratory for STAR, which was designed to identify and study the phase transition between normal nuclear matter and quark matter (the so-called quark-gluon plasma). In the past year, the collaboration has published seven papers focusing on measurements of elliptic flow, resonance production, and production of high p_T particles and jets in Au+Au and p+p collisions. The STAR Parallel Distributed Systems Facility (PDSF) computing facility at Berkeley Lab (which complements the RHIC Computing Facility at Brookhaven) is now in production mode. It has been essential for STAR and also for SNO and KamLAND data analysis efforts. Berkeley Lab is establishing a RHIC spin component to its current high-energy physics program. Looking further to the future, Berkeley Lab scientists are designing a next-generation, high-resolution vertex detector for STAR to enable the measurement of the very short-lived D mesons, and are also leading the ALICE-USA collaboration to participate in the LHC heavy-ion program.

Neutrino science made the headlines in 2002 (including the award of a Nobel Prize) and Berkeley Lab scientists played a major role. New results from the Sudbury Neutrino Observatory (SNO) established neutrino flavor transformation and validated the Standard Solar Model's prediction of the ^{8}B neutrino flux from the sun. These results mean that neutrinos necessarily have mass, which required the first modification of the Standard Model of particle physics in thirty years. The results also indicated that the Large Mixing Angle (LMA) was the favored solution. Later in the same year KamLAND—a new reactor neutrino experiment in Japan—announced its first results indicating a disappearance of anti-neutrinos at a 99.95% confidence level and in an amount that confirmed the LMA solution. The results of SNO and KamLAND together identify matter-enhanced oscillations as the explanation of "the solar neutrino problem" and are responsible for the conversion of two-thirds of the sun's neutrinos from electron-type neutrinos into other families. Both experiments are continuing their pioneering studies of neutrino oscillations. Laboratory scientists are also participating in the Cryogenic Underground Observatory for Rare Events (CUORE/Curoricino), a neutrinoless double-beta decay experiment to be staged in the Gran Sasso facility in Europe. They are also exploring possible participation in another double-beta decay experiment, Majorana, which would incorporate the GRETA technology. Next-generation experiments and detectors in neutrino science and double-beta decay are being developed for deployment in a proposed underground laboratory to further probe the neutrino properties and mixing, and to exploit the unique opportunities afforded by detection of high-energy neutrinos.

The year 2002 was also a good year for the Berkeley Lab low-energy research program. In a study of nuclear properties at high temperature, compound damping widths and rotational damping widths were accurately determined from energy correlation analysis for the first time. The liquid-vapor coexistence line of finite nuclear matter was constructed. This is a major step in the quantitative understanding of the nuclear phase diagram and generated several articles, including contributions to *APS News, New Scientist,* and *Physics Today*. The chemical properties of element 108 were studied in a collaborative experiment at GSI in Germany using equipment developed at Berkeley Lab. Taking advantage of the high efficiency of Gammasphere, new limits on charge conjugation and charge, parity, and time (CPT) violation were set by studying the rare four- and five-photon decay of positronium. Gammasphere completed its second successful campaign at the 88-Inch Cyclotron and has now moved to ANL to continue its forefront nuclear structure program.

The 88-Inch Cyclotron has been the center of a broad and versatile nuclear structure and reactions research program for four decades, not only for Berkeley Lab, but also for the entire international low-energy research community. Plans have been developed in partnership with the U.S. Air Force Office of Research to continue using and supporting the 88-Inch Cyclotron for space radiation simulation studies and to continue the Berkeley Lab forefront program. Coupling of the existing atom traps and Electron Cyclotron Resonance (ECR) sources, for example, would allow the world-class trapping program to continue exploring fundamental symmetries, and would also present new physics opportunities.

DOE Nuclear Physics is moving forward with planning for an advanced radioactive beam facility, the Rare Isotope Accelerator (RIA), as recommended in the 2002 Long-Range Plan. The nuclear physics identified covers a broad range of topics, including nuclear structure, nuclear astrophysics, exotic nuclei, and heavy elements, requiring both stable and radioactive beams. Berkeley researchers expect to play a strong role in both the science and the technology of RIA, and are currently participating in RIA research and development activities. During the past year, great progress was made on both VENUS, a third-generation ECR ion source, and GRETA, a next-generation gamma-tracking array (see Section IV, Initiatives). GRETA will be one of the major detectors to address RIA physics, and we expect that VENUS, originally designed to provide intense heavy-ion beams at the 88-Inch Cyclotron, will serve as a prototype ion source for the RIA driver.

In addition, the Laboratory works with the Office of High Energy and Nuclear Physics as landlord and steward for the Laboratory's General Purpose Equipment and General Plant Projects essential for the maintenance and scientific infrastructure of the Laboratory, as well as waste management operations. The Stewardship Committee brings together program representatives and Laboratory managers to address the operational and infrastructure needs of the Laboratory.

Workforce Development for Teachers and Scientists

Berkeley Lab provides for the education and training of future scientists, computer scientists, engineers, and technicians to meet the mission of the Department of Energy (DOE). Graduate and undergraduate students are educated and trained through mentored research participation. Precollege programs promote careers in science and technology through staff visits to classrooms, tours, workshops, and summer work opportunities for high-school juniors and seniors and science teachers. Education partnerships and outreach focus on local schools and colleges, ensuring the participation of a diverse population of students.

Graduate students are supported through research programs. Local undergraduates are hired as part-time student assistants. The Office of Science supports undergraduate student and faculty fellowships, which are provided through the Laboratory's Center for Science and Engineering Education (CSEE). Programs include the Student Undergraduate Laboratory Internship (SULI), the Community College Institute (CCI), the Preservice Teacher Program (PST), and Faculty Student Teams (FaST). Berkeley Lab recruits student from minority-serving institutions to increase representation of underrepresented minorities in science and engineering in the national SULI and CCI applicant pool. Berkeley Lab has a partnership with an NSF-funded program at California State University, Fresno to leverage support for PST student fellowships. The Faculty Student Team Research program is being adopted at Berkeley Lab as a strategic way to both increase workforce diversity and create research partnerships that will lead to competitive research grants from colleges and universities across the country.

Education outreach includes programs that utilize the human and technical resources of the Laboratory to promote careers in science and technology, support science, mathematics, and technology teachers, and lead to the improvement of science education in high schools, middle schools, and elementary schools. Partnerships focus on local urban school districts. The Center for Science and Engineering Education facilitates DOE programmatic activities in its education outreach and coordinates its efforts with the Office of Workforce Diversity and with Public Affairs.

Office of Energy Efficiency and Renewable Energy

The Berkeley Lab program in Energy Efficiency and Renewable Energy comprises an integrated set of activities that provide research support and technology development in the furtherance of national goals to reduce carbon emissions, urban and regional air pollution, and cost to consumers, as well as to enhance energy security. These activities have been organized into building, electrical power, industrial, and transportation technologies. Berkeley Lab has had a leadership role in the interlaboratory studies on carbon management and the National Transmission Grid study, and participated in the preparation of the DOE Power Outage Study Team's report on policies to improve electric reliability.

Building technologies at Berkeley Lab will continue activities related to residential and commercial buildings in a program of laboratory and field research, modeling, data analysis, and partnerships with industry to accelerate market impact of our research. This work is a coordinated systems approach to designing building components, as well as entire buildings, with improved energy efficiency and better conditions for human health, comfort, and productivity.

Research continues on advanced window systems, including the development of electrochromic coatings for the active control of the transmission of light and infrared radiation. Advanced lighting fixtures are being developed to facilitate the increased use of energy-efficient lamps, such as compact fluorescents, as well as fundamental materials research for alternatives to existing room lighting. Ongoing research is aimed at a next generation of building energy simulation and design tools, including ones that will encourage increased use by practitioners (e.g., architects) and provide advanced computational methods for the research community. Work continues on infiltration, ventilation, airflow, and thermal distribution in the interests of having energy-efficient buildings while maintaining desired indoor air quality levels. Technical assistance activities are carried out in support of DOE new construction and retrofit programs such as Rebuild America. Technical and economic analyses continue to support DOE's setting of energy standards for appliances and lighting, and for understanding the energy use of home and office electronic equipment. Technical assistance is also provided to the Federal Energy Management Program (FEMP), which is charged with helping federal agencies use energy more efficiently.

The work in electrical power technologies includes a geothermal energy resources program that consists of delineation and evaluation of geothermal systems, definition of reservoir processes, modeling of reservoir dynamics and exploitation effects, and analysis of field-management practices. Fluid production and injection technologies are also being studied to optimize reservoir management. In addition, Berkeley Lab undertakes a variety of analysis activities on issues and opportunities that may impact renewable and distributed energy technologies, including the restructuring of the electric utility industry, energy demand and energy technologies in developing countries, and specific renewable technologies for the U.S., including high-temperature superconductors for electric power transmission. Berkeley Lab manages the multi-institution Consortium for Electricity Reliability Technology Solutions (CERTS)—a joint effort between DOE and the State of California.

Industrial technologies focuses on advanced industrial concepts. Berkeley Lab is participating in the Industries of the Future program, which includes the development of sensors and control systems for improved energy efficiency and productivity in the pulp and paper industry. New efforts are exploring more energy-efficient extraction techniques for the mining industry, and a Berkeley Lab-developed low nitrogen oxide emission natural gas burner for boilers and furnaces. Berkeley Lab also provides support for government/industry programs, such as those for the more energy-efficient use of electric motors.

In transportation technologies, Berkeley Lab manages the Batteries for Advanced Transportation Technologies (BATT) Program, which seeks to advance the development of high-energy rechargeable batteries for use in electric vehicles. In the new Advanced Technology Development (ATD) program, Berkeley Lab is working with other DOE multiprogram laboratories in studying the degradation mechanisms in high-power batteries for hybrid vehicles. Berkeley Lab is also working in conjunction with the other DOE laboratories to assist DOE in its role in federal/industry partnerships for advanced vehicles, including Freedom CAR, by applying its expertise to combustion and emissions, fuel cells, lightweight materials, and improved manufacturing techniques. Some of this work, in particular the characterization of diesel particulates, is applicable as well to heavy vehicles, such as trucks and sport-utility vehicles.

Office of Civilian Radioactive Waste Management

Berkeley Lab continues a strong multidisciplinary program of interrelated geoscience and geological engineering research important to the safe, long-term underground storage of high-level nuclear wastes. This research includes characterization of deep geologic formations, determination of the physical and chemical processes occurring in the repository rocks, analysis of hydrologic and chemical transport mechanisms, and development of predictive techniques for repository performance. Coupled with ongoing basic research, Berkeley Lab’s Yucca Mountain Project site characterization research was important to DOE’s recent decision to proceed. The Laboratory is also contributing to international radioactive waste management projects in cooperation with Sweden, Switzerland, Canada, and Japan. Much of the work is funded through other DOE contractors (see below).

Office of Fossil Energy

Berkeley Lab conducts basic research for the Office of Fossil Energy. Research projects are directed toward making coal more usable, and include studies on emissions reduction. The research includes new catalytic processes for the sequestration of carbon dioxide and the simultaneous catalytic reduction of nitrogen dioxide and sulfur dioxide from flue gas.

Berkeley Lab participates in a number of oil and gas projects in conjunction with many oil and gas producers. The goal of this work is to bring advanced technologies developed at the laboratories to the stage where producers can use them to increase production or to decrease the uncertainties and costs for drilling new exploration and production wells. Because of its expertise in underground imaging technologies and research related to various aspects of heat and mass transport in the crust, including reservoir dynamics, the Earth Sciences Division leads several collaborative projects related to increasing oil and gas production. A particular emphasis has been on using graphical methods for enhancing production from natural gas fractural reservoirs. The earth science studies include the use of subsurface imaging, modeling, measurement and scaling of multiphase flow processes; integrated reservoir monitoring using seismic and cross-well electromagnetics; frequency-dependent seismic attributes of fluids in poorly consolidated sands; and the development of single-well seismic imaging technology. Through the Environmental Energy Technologies Division, Berkeley Lab also conducts research into the effect of petroleum production and refining activities on air quality, particularly on understanding and being able to predict the concentration of fine-grained, air-borne particulates down to 2.5-micron size. Determining the indoor concentrations of outdoor pollutants that have entered a building is crucial since people spend 90 percent of the time indoors, 70 percent in homes.

Berkeley Lab has a Partnership effort underway to help the oil industry find more economical and efficient ways to lower the viscosity of heavy crude oils, and during the next five years, Berkeley Lab expects to participate in new Partnership projects related to clean fuels initiative.

Berkeley Lab also conducts oil and gas applied research over a wide range of topics outside the Partnership program. These projects include research into multiphase fluid flow at a state-of-the-science pore-scale rock imaging laboratory, enhanced oil recovery using foams to control oil and water mobilities, and development of instrumentation to accurately characterize emissions from oil storage tanks in order to help the petroleum industry meet air quality regulations.

Berkeley Lab will lead a new multilab and industry project to investigate the sequestration of carbon dioxide—a greenhouse gas—in geologic formations including depleted oil and gas reservoirs, brine formations, and coal beds.

Environmental Restoration

Berkeley Lab is implementing site projects for restoration and waste management consistent with DOE's National Environmental Management Program. In collaboration with other laboratories, Berkeley Lab will help address major technology gaps in environmental restoration. Components are improved characterization of subsurface environments, development of methods for assured containment and control of contamination, development of advanced remediation technologies, and improved risk-assessment and prioritization systems. The methodologies include field testing and tracking contaminant fronts; developing descriptive and predictive mathematical models; characterizing heterogeneous underground systems; designing, demonstrating, and testing containment and cleanup systems at specific contaminant sites; and determining the underlying chemical, biological, and thermodynamic properties involved in mixed contamination.

Office of Environment, Safety, and Health

Berkeley Lab is continuing its programs in analytical methods development and statistical studies of environmental and epidemiological factors supported by the Office of Epidemiology and Health Surveillance. The Population at Risk to Environmental Pollution Project focuses on the collection, analysis, and interpretation of data pertaining to relationships between human health and environmental pollution. Computational techniques are developed to analyze ecological data, especially small-area geographic data, to investigate alleged departures from expected disease rates, to generate etiologic hypotheses, and to plan clinical trials or cohort studies.

National Nuclear Security Administration

Berkeley Lab's unique capabilities in accelerators have been utilized in an unclassified project to design, fabricate, and commission the induction electron accelerator for the second axis of the Dual Axis Radiographic Hydrodynamic Test Facility (DARHT) at Los Alamos. Expertise in induction linacs is instrumental to this effort to deliver an advanced induction electron linac for DARHT, which takes advantage of developments originating in the Office of Science Fusion Energy Sciences Program.

Past research on ion sources for application to neutral beam plasma heating and for particle accelerators has allowed Berkeley Lab to contribute a new generation of neutron sources to NNSA's technology base. Two programs are currently underway for NNSA. The first will provide a compact, high flux point neutron source for a neutron radiography program at LANL. The second is a high flux neutron source for cargo container screening. This second project is being carried out jointly with LLNL, which has the overall system responsibility. Application of these new sources to other NNSA programs at Idaho National Engineering and Environmental laboratory (INEEL) is being explored with NNSA management.

Berkeley Lab's long involvement with radiation detection in the Engineering Division continues to provide valuable research to the NNSA in the area of Cadmium Zinc Telluride (CZT) room-temperature gamma detection. Work supported by the Office of Biological and Environmental Research and by the National Institute of Bio-Medical Imaging and Bioengineering at the Center for Functional Imaging for medical applications has led to strong NNSA interest in a potential program to explore the inorganic crystal database for promising new radiation detector materials, especially fast high-efficiency scintillators.

The Energy and Environmental Technology Division provides ongoing research to NNSA in laser ablation mass spectroscopy for application to nuclear weapon proliferation detection.

Berkeley Lab conducts research in support of the national DOE program on Initiatives for Proliferation Prevention. This research is conducted in partnership with other laboratories and with foreign organizations in countries where proliferation prevention is an important U.S. goal. Examples of the research include treatment of nuclear and non-nuclear waste by electron beam assisted plasma chemistry, agricultural crop protection through microbially derived materials, and the development of magnet and accelerator systems for free electron lasers.

Work sponsored by NNSA in the past on chemical and biological counterterrorism technology has been moved in FY 2003 to the new Department of Homeland Security. For discussion of Berkeley Lab's involvement in those programs please see "Department of Homeland Security" below.

Other DOE Contractors

To optimize the use of the Integrated System of Laboratories, Berkeley Lab conducts research for DOE missions in partnership with other DOE Laboratories and contractors. Projects include:

- A multidisciplinary program of interrelated geoscience and geological engineering research important to the safe, long-term underground storage of high-level nuclear wastes in a program administered by Bechtel SAIC Company (BSC) for the Office of Civilian Radioactive Waste Management. Coupled with ongoing DOE basic research, Berkeley Lab is contributing to technology, site characterization, and applied development research at the Yucca Mountain Project. The research includes characterization of deep geologic formations, determination of the physical and chemical processes occurring in the repository rocks, analysis of hydrologic and chemical transport mechanisms, and development of predictive techniques for repository performance.
- Berkeley Lab has lead responsibility for research, design, and fabrication of the Front End for the Spallation Neutron Source being constructed at the Oak Ridge National Laboratory. The accelerator

Front End has been completed and has been installed at the SNS. The Laboratory is now working on the low-level radiofrequency power system for the SNS accelerator.

- Berkeley Lab coordinates the Energy Sciences Network (ESnet), including projects with other DOE institutions on security and network access, maintaining ESnet lines, access, and services (some of this work is funded by other contractors).
- Berkeley Lab is in collaboration with Los Alamos National Laboratory for the development of high-temperature superconductors.
- Berkeley Lab conducts research in collaboration with other laboratories for accelerator research, including beam characterization for radiobiological research at Brookhaven National Laboratory, ion source development, and magnetron development.
- Berkeley Lab conducts advanced detector and instrumentation research and development in partnership with many high-energy and nuclear physics laboratories—these include vertex detectors, charge-coupled device cameras, and detectors.
- Berkeley Lab conducts a range of earth sciences research with other laboratories, including salt dome imaging research and geothermal reservoir technology research.

In addition, the Laboratory performs collaborative research with other DOE laboratories in energy efficiency, chemical and materials sciences, and in environmental sciences, which includes the areas of sustainable energy development, efficient catalysts, subsurface characterization of contamination, and the effects of ultraviolet light.

Certain offices within DOE support formal partnerships in which the prime institution is a private company or university, but a national laboratory can be a partner through a subcontract with the prime. Such efforts include one on energy-efficient solid state lighting with Cree Lighting, and solid state light sources with UC San Diego.

Department of Homeland Security

The national welfare is dependent on advanced technology to support homeland security and on the underlying capabilities of fundamental and applied science. The Office of Science and other DOE departments, including the Office of Energy Efficiency and Renewable Energy, support research that is essential for the nation's need to detect, prevent, and respond to terrorist attacks involving chemical, biological, and radiological threats. Further support of this research has the potential to impact a broad set of technology needs, providing significant return on research investments.

There are two governing elements to aid Berkeley Lab in selecting and promoting the most useful research for homeland security. First, the Laboratory is pursuing an integrated analysis capability to assess the vulnerabilities and connectivities important to critical infrastructures in order to identify a suite of technologies for threat reduction and consequence mitigation. Second, the Laboratory is supporting local organizations so that the actual needs of local stakeholders and groups in municipalities will have impact on technology development. Some of the science Berkeley Lab offers for this national need is listed below:

- **Aerosol Transport Modeling.** Advanced modeling systems to predict and analyze the transport of hazardous agents in buildings and the environment is an important application of DOE science and technology to understand and respond to atmospheric or waterborne hazards. Berkeley Lab has indoor and outdoor air transport modeling capabilities with hazards analysis applications. The Laboratory initiated and continues to improve the Conjunction of Multizone Infiltration Specialists (COMIS) model, which is the most advanced system for understanding the distribution of indoor air contaminants. This tool has been essential for the design of "smart" buildings and as a tool for first responders. Research on attachment of aerosolized biological agents to surfaces and their survival would improve development of realistic tools. The Laboratory also has capabilities in the areas of hydro-meteorology and waterflow into and out of aquifers. This is useful for assessing the potential for chemical and biological attacks on water supplies. In addition, Berkeley Lab is conducting research on the biology and ecology of microbes (using nontoxic organisms) that, combined with the water supply tools discussed above, gives a more complete understanding of biohazard threats. Other research in chemical vapor detection is based on bacterial chemotaxis.

- **Compact Neutron Sources.** Field-deployable, high-intensity, short-pulse neutron sources are ideal systems for detecting and characterizing explosives and many other materials. Berkeley Lab has developed a new generation of neutron tubes, which can produce two-to-three orders-of-magnitude improvement over those currently available. This research is described in the NNSA section.
- **Environmental Characterization.** Berkeley Lab conducts research in bacterial survival and use in the natural environment, including mapping biochemical contaminants with bacteria. It contributes to studies of natural biological background to help distinguish man-made attacks from natural outbreaks, creates databases that reduce the probability of false positive detections, and studies the survivability of microbial agents in the environment. Isotopic geochemistry can locate materials based on variations in isotope levels around the world. Geophysics and water resources experts can contribute to locating and characterizing underground facilities, and to performing threat analysis on domestic water supplies.
- **Forensics and Analysis.** The Advanced Light Source (ALS) provides a variety of synchrotron-based tools useful for analytical and surface chemistry work, including forensics and biological research. The National Center for Electron Microscopy has forefront capabilities with potential for forensics and surface science.
- **Structural Biology.** Protein crystallography beamlines at the ALS and associated robotics and processing software allow for rapid determination of protein structure relevant to design of protein-based assays for pathogens.
- **Information Technology.** The computer scientists are contributing to information security via studies of (a) information processing and retrieval technology for detecting and identifying terrorists from text-based and network-based databases, (b) data-protection technology, which is essential for the preservation of the national infrastructure, (c) secure and reliable multicast development and deployment for monitoring and information-sharing, (d) computational and informatics techniques for model recovery from observed images and video streams, and (e) simulation of explosions and deflagrations in underground chambers.
- **Infrastructure Protection.** Berkeley Lab hosts the Program Office of the Consortium for Electric Reliability Technology Solutions (CERTS), which specializes in the protection of electrical transmission infrastructure and the development of distributed power technologies, such as fuel cells.
- **Ultrasensitive Detectors.** Berkeley Lab is conducting research on several new advanced detection methods for hazardous agents that offer unique sensitivity and characterization capabilities. One major advance is high-resolution nuclear magnetic resonance (NMR) spectroscopy for highly portable field use. Berkeley Lab also is investigating sensitive and fast instrumentation; techniques for detecting pathogenic organisms or molecules using a Superconducting QUantum Interference Device (SQUID); and microdevices for a hand-held chemical agent detector in a program with Sandia-Livermore.

Work for Others General Trends

Berkeley Lab has many unique facilities and scientific resources that are made available to other government agencies, universities, and industry in support of DOE's mission and consistent with its policies. The customers for this work and the associated areas of research complement DOE's mission areas, and the levels of funding provided by these agencies is indicated in Section VIII, Resource Projections and Tables.

The proportion of support from non-DOE sources is expected to remain approximately level (18 to 23 percent of the total Laboratory budget). The actual projections for FY 2003 and out years in the resource tables indicate best estimates of about 20 percent. The Laboratory's DOE mission areas that hold the strongest interest for collaboration by other organizations include Biological and Environmental Research, Basic Energy Sciences, Energy Efficiency and Renewable Energy, and in the future, High Energy and Nuclear Physics. The Laboratory Directed Research and Development program has directly contributed to the underlying research capabilities sought by Work for Others sponsors. Several key Work for Others trends include:

- The Advanced Light Source is expected to increase its user base from over 1,600 users this year to about 2,000 by 2004. Concomitant with this increase is support in structural biology and x-ray crystallography from the National Institutes of Health and from private sources, such as the Howard Hughes Medical Institute. Other users in materials sciences, chemistry, and environmental science can be expected, including funds-in for beamline development and beamline operation. New detector and beamline capabilities have been demonstrated as valuable resources for Work for Others health research and industry sponsors.
- Other sponsors of sequencing, functional genomics, and computational biology have an increasing interest in the Office of Biological and Environmental Research capabilities associated with the genome program at Berkeley Lab and the DOE Joint Genome Institute, and the modeling capabilities of the Physical Biosciences Division. Primary sources include the National Institutes of Health, U.S. Department of Agriculture, U.S. Environmental Protection Agency, the National Science Foundation, and the Defense Advanced Research Projects Agency (DARPA).
- The Laboratory's internationally recognized programs in cell and molecular biology are attracting support from the National Institutes of Health as well as the Department of Defense (for breast cancer, prostate cancer, and DNA repair studies) and biotechnology companies.
- Research in materials sciences that takes advantage of the capabilities at the Advanced Light Source, the National Center for Electron Microscopy, and the Center for X-Ray Optics is being sponsored by other agencies. Primary sponsors are the Defense Advanced Research Projects Agency and private industry. Cooperative Research and Development Agreements for this work are tabulated separately from Work for Others.
- The Environmental Protection Agency (EPA) and the State of California are sponsoring research that builds upon Berkeley Lab's expertise and experimental facilities in the buildings and electricity reliability areas.
- In the area of high-energy physics, the Laboratory is working with DOE, NSF, and NASA to develop and implement a SuperNova/Acceleration Probe. Although most of the funding to the Laboratory is expected to come from DOE, there is the potential for additional NSF and NASA funds coming to the Laboratory. Because of the uncertainty in scope and budget, these Work for Others funds are not included in the projections at this time.

National Institutes of Health

DOE biosciences and environmental programs at Berkeley Lab are valuable to the National Institutes of Health (NIH), which supports research closely coupled to DOE programs. Several critical technologies—specifically genome sequencing, molecular medicine, biotechnology, and structural biology—build on the unique facilities and expertise available at Berkeley Lab. The NIH applies the Laboratory's unique resources to investigations in many of its institutes.

- For the National Institute of General Medical Sciences (NIGMS), the Life Sciences Division conducts research in high-resolution electron crystallography of proteins. The research, using unique instrumentation and expertise, has lead to a breakthrough in revealing the structure of tubulin and other critical biological molecules. NIGMS is sponsoring a new protein structure effort at Berkeley Lab, which couples to the Laboratory's Advanced Light Source and instrumentation engineering capabilities, led by investigators in the Structural Biology Department of the Physical Biosciences Division.
- For the National Heart, Lung and Blood Institute (NHLBI), the Life Sciences Division is conducting research in cardiovascular flow and metabolism under the Programs for Genomic Applications, a multi-investigator initiative using a comparative genomic approach to identify and determine the function of elements regulating the expression of genes affecting the cardiovascular system.
- For the National Institute of Diabetes and Digestive and Kidney Diseases, the Life Sciences Division is conducting research in red cell membrane studies to obtain a detailed understanding of the selected red cell skeletal proteins in regulating membrane function through characterization and manipulation of the corresponding cloned genes.
- For the National Cancer Institute, the Life Sciences Division is conducting a broad program of research in breast cancer and DNA repair.
- For the National Institute on Aging, the Life Sciences Division is conducting research to determine the causes and consequences of cellular senescence, the function of DNA repair proteins in cellular and organismal aging phenotypes, and the regulation and function of telomeres in genomic stability, cancer, and aging.
- Important initiatives now underway in collaborations between Office of Science/OBER and NIH are described below in the initiatives "Genomes for Energy and the Environment: Genomes to Life" and "Molecular Machines for Maintaining Genomic Integrity" (see Section IV, Initiatives).
- For the National Institute for Biomedical Imaging and Bioengineering (NIBIB), the Life Sciences Division is conducting research to improve scintillators for positron emission tomography, and to improve algorithms for image reconstruction.
- NIH also supports programs on radionuclides, nuclear magnetic resonance imaging, diagnostic image reconstruction, radio-pharmaceuticals related to advanced instrumentation and disease treatment, and use of nanocrystals in biological and biomedical imaging.

Berkeley Lab has recently initiated studies in four critical areas for DOE and NIH: (1) using transgenic animal models to study the relationship between genomic variations and the occurrence of atherosclerosis, (2) studying relationships among neuroreceptor concentrations, brain metabolism, mental disorders, and the genome, (3) developing labeled DNA probes for understanding inflammatory diseases, autoimmune conditions, atherosclerosis, and cancer, (4) and monitoring gene therapy.

Department of Defense

DOE's unique facilities at Berkeley Lab are valuable for unclassified research projects in the Department of Defense (DOD). The Center for X-Ray Optics has received funding from the Defense Advanced Research Projects Agency (DARPA) for beamline development at the Advanced Light Source (in extreme ultraviolet interferometry and extreme ultraviolet metrology) and for electron-beam lithography. DARPA also funds testbeds that combine high-speed, wide-area-network technology, distributed image-storage systems, and high-speed graphics with aerial and satellite images to create a virtual-reality simulation of terrain travel. In addition, DARPA (through Lawrence Livermore National

Laboratory) is funding work to advance the modeling of chemical and particle dispersion in multizone buildings. While the Agency's concern is toxic agent releases, the methodology will be applicable to indoor pollutants generally. This effort is complementary to the work described in the section on Homeland Security (see above). Other work supported by DARPA includes the application of combinatorial chemistry to advanced materials. The Office of Naval Research (ONR) supports optical scattering characterization of marine visibility.

All DOD research conducted on site at Berkeley Lab is unclassified. The larger projects include:

- For the Department of Defense, the Life Sciences Division conducts a major breast cancer research program to analyze a large number of existing aggressive tumor cell lines and primary tumors in order to find novel ways of normalizing them with combination treatments that can reverse the malignant behavior of the cells.
- For ONR, the Physical Biosciences Division conducts a program for engineering biomolecules and biological processes to create novel cell-based sensory and signaling systems.
- For DARPA, the Accelerator and Fusion Research Division conducts research on the production and manipulation of beamlets, which if coupled with beam reduction and acceleration systems, can provide novel maskless approaches to microlithography for high-throughput semiconductor processing.
- Also for DARPA (through Lawrence Livermore National Laboratory) and Defense Threat Reduction Agency (DTRA) the Environmental Energy Technologies Division conducts research on chemical and biological transport in buildings.
- An important biological modeling initiative now underway in collaborations between Office of Science/OBER and DARPA is described below under "Genomes for Energy and the Environment: Genomes to Life" (see Section IV, Initiatives).

National Aeronautics and Space Administration (NASA)

Berkeley Lab conducts biological, astrophysical, and materials science research sponsored by NASA that is complementary to DOE's mission. The Berkeley Lab Astrophysics Group has been instrumental in the understanding of anisotropies in the cosmic microwave background. These anisotropies show the primordial seeds of modern structures such as galaxies, clusters of galaxies, and larger-scale patterns. NASA also supports analysis of Hubble Telescope data in the Supernova Cosmology Project, which has recently discovered that the universe is expanding at an accelerating rate. Berkeley Lab also undertakes research in aerogel-based materials, combustion under micro-gravity conditions, carbonaceous aerosols in the atmosphere, and remote sensing of land-use changes.

Another area of research is on the space radiation environment and its implications for human presence in space. The project utilizes unique radiobiological research expertise and instrumentation at Berkeley Lab. Laboratory investigators are conducting multidisciplinary research at the molecular, cellular, and tissue levels for understanding the biological impact of solar and galactic cosmic radiation exposure on astronaut health and that of future colonizers.

Research in the Earth Sciences Division is carried out under NASA's Regional Earth Sciences Applications Center, as well as studies on an autonomous profiler for carbon systems and biology.

Computational research supported by NASA includes spectrum synthesis of supernovae, development of cosmic microwave background analysis tools, and development of adaptive mesh refinement algorithms for simulating plasma effects in the magnetosphere. Berkeley Lab also provides program management for the Information Power Grid, NASA's high-performance computational grid.

Environmental Protection Agency (EPA)

Research sponsored by the Environmental Protection Agency directly complements DOE's environmental and energy-efficiency missions. Berkeley Lab conducts research on imaging non aqueous phase contaminant plumes and the hydrogeological transport of plumes from deep underground injection disposal. In the area of global environmental effects, Berkeley Lab is characterizing the emissions of energy technologies, improving global energy projections, providing technical assistance to China in developing efficient energy technologies, fostering international awareness of global trends, and studying effects of tropical deforestation. Berkeley Lab, along with other national laboratories, is also working to develop new ways to advance national environmental goals, including the more efficient use of energy to reduce greenhouse gas emissions. Berkeley Lab is also undertaking research on understanding the transport, transformation, and human exposure to environmental pollutants. Berkeley Lab is sponsored by EPA to develop building energy-efficiency analysis software and a supporting Web site. One of the larger projects is a study of heating, ventilation, and air conduction systems that focuses on building-sector market analysis potential. Other work supported by EPA includes mitigation strategies and technologies for urban heat islands, and the analysis of energy use in industrial processes. Also note JGI activity discussed below in "Other Federal Agencies."

Department of the Interior

Laboratory scientists are investigating the geochemistry of selenium and other trace elements at Kesterson Reservoir, a terminus of agricultural drainage water in California's San Joaquin Valley. Continuing collaborative investigations are underway to evaluate remediation techniques for the area's soil, with related research at Stillwater Marsh, Nevada.

Agency for International Development

The U.S. Agency for International Development (USAID) is supporting a multiyear effort in which Berkeley Lab performs research on improving the efficiency of energy use in developing countries.

Other Federal Agencies

The U.S. Postal Service supports work at Berkeley Lab on energy-efficient technologies for postal buildings. In conjunction with the Joint Genome Institute, sequencing projects on plant and plant pathogens are conducted for the Department of Agriculture, and sequencing projects of environmental sentinel species are conducted for the Environmental Protection Agency. The Laboratory has also contributed to the poplar tree genome database and conducted tritium labeling for the Department of Agriculture. The Laboratory has contributed to a materials surface structure database for the Department of Commerce. The Laboratory conducts a particle data program and develops educational materials for the National Science Foundation.

State Organizations

In the energy area, for many years funding from the State of California has complemented that provided by DOE, particularly for building technologies and electric reliability. Much of the results of the research have been incorporated in products available in the market and in the State's building codes and standards. A Memorandum of Understanding between the California Energy Commission (CEC) and DOE supports a larger role for Berkeley Lab in the CEC's Public Interest Energy Research (PIER) program, which receives funding from the California electricity ratepayers. Certain energy-efficient buildings and other research projects of the type formerly supported by the California Institute for Energy Efficiency (CIEE) are now part of this program, and new projects are underway. These include projects on energy-efficient lighting, thermal distribution systems in commercial buildings, next-generation power-management user interface for office equipment, and an instrumented home energy rating and commissioning system. Major programs now underway address efficient building systems and "high-tech" buildings such as clean rooms and data centers. The electricity system reliability work involves co-sponsorship with DOE of the Consortium for Electric Reliability Technology Solutions (CERTS).

Certain aspects of the CEC's PIER program are being managed by CIEE, which organizationally is in the UC Office of the President. Work supported by CEC through CIEE included low-energy cooling systems for commercial buildings and research on climate change in California. The Laboratory is also providing technical assistance to the City of Oakland to retrofit government buildings to be more energy-efficient. The support is from the California Public Utilities Commission, through Quest, Inc.

Recent work through the geothermal program is on using microearthquake analysis to understand the impact of fluid injection on steam production of the Geysers.

The California Breast Cancer Research Program was established after passage of the Breast Cancer Act by the California legislature in 1993. The program supports research in the life sciences to reduce the human and economic costs of breast cancer in California.

Under the University of California Tobacco Related Disease Research Program, the Laboratory investigates various aspects of secondary tobacco smoke. A study just getting underway for the California EPA is addressing the relationship between childhood asthma and school children's exposure to vehicle exhaust emissions.

Private Firms and Organizations

Berkeley Lab conducts research under the sponsorship of private firms and private organizations where its unique expertise or facilities are of specific value. For example, the Electric Power Research Institute sponsors studies on the reduction and oxidation involved in scale formation, oxygen depletion in compressed-air storage, diffusion-based sampling of semi-volatile and particulate carbonaceous species, and surface modification with metal plasma techniques. The Gas Research Institute supports databases on the influence of clays on seismic-wave attenuation in reservoir rocks. Some of the larger projects for the private sector include:

- A beamline for biological crystallography is now operational at the ALS, managed through the Physical Biosciences Division under sponsorship of the Genomics Institute of the Novartis Foundation. This beamline features advances in robotics and high-throughput automation.
- The Howard Hughes Medical Institute has made a major investment in funding two superbend beamlines at the ALS also supporting research in protein crystallography.
- Research being conducted by the Environmental Energy Technologies Division includes sustainable energy in China under sponsorship from the Energy Foundation, Shell International; international appliance standards under sponsorship of the Alliance to Save Energy; and foundation support for efficient water treatment systems in underdeveloped countries.
- A DOE collaborative program on mass transport is being conducted by the Earth Sciences Division under support of the Power Reactor and Nuclear Fuel Development Corporation.
- Research for the development of an automated environment for the construction of sorted cDNA is being conducted by the Engineering Division under the sponsorship of the Amgen Corporation.

Other studies include novel ion sources, studies of fuel oxidation, combinatorial chemistry for advanced materials, thermal management systems, silicon particle detectors, oil reservoir characterization, seismic cross-well monitoring, membrane protein studies, materials microcontamination studies, studies of radiation hardened circuits, science issues of social significance, and x-ray crystallographic studies and beamline development.

Universities

Berkeley Lab conducts research in partnership with universities and international organizations where its unique expertise or facilities are of specific value to such collaborations. The projects are in many fields, including physics, chemistry, materials sciences, geosciences, and biology. In addition to the research projects, Berkeley Lab science education activities are conducted in partnership with the University of California (UC) and the State of California. The larger university- and international-organization-sponsored projects are:

- The Laboratory, in a partnership with the University of California at Berkeley, has completed the sequencing and annotation of the euchromatic genome of *Drosophila melanogaster*.
- The Center for Nutritional Genomics is a partnership between Berkeley Lab, UC Berkeley, and the U.S. Department of Agriculture Western Human Nutrition Research Center. The mission of the Center is to identify the effects of nutrition on gene expression and function in humans and model organisms, and to study the influence of genetic variation on human nutrition and optimal health. The Center will also investigate genetic modifications to enhance the nutritional value of plants.
- Research on aging will integrate the efforts of UC Berkeley and Laboratory geneticists, physiologists, cell and molecular biologists, and structural and computational biologists to understand the basic processes that are responsible for aging at the molecular, cellular, tissue, and organismic levels. The Center for Research and Education in Aging, lead by a UC Berkeley professor, is designed to create a research training and education environment that will increase the number of advanced degrees in the area of aging research.

Other topics include energy demand and transportation, atomic force microscopy, beamline development at the ALS, x-ray holography and tomography, genome studies, physics detectors, subsurface monitoring, breast cancer, transgenic studies, cell aging, 10-meter telescope control systems, and atomic-scale studies of catalysts.

Laboratory Directed Research and Development (LDRD)

The Berkeley Lab LDRD program is a critical tool for strengthening the Laboratory's research capabilities to meet the needs of DOE and the complementary interests of other research sponsors. The program provides the resources for Berkeley Lab scientists to develop new capabilities to make rapid and significant contributions to critical national science and technology problems that will be valuable to a broad range of federal and other sponsors.

Within the last year, LDRD funds were allocated to *Physical Sciences* research in, for example, novel liquid crystal phases; synthesis of novel tough materials based on the concept of artificial bone; cooperative effects determining fidelity in cellular recognition; condensation of indirect excitons in coupled quantum well nanostructures; nanoscale electronic phase separation: a new paradigm for complex electronic materials; surfactant mediated epitaxy of IV-IV compounds; holographic imaging with x-rays; and teraflop challenges in single-particle electron crystallography. Research efforts in the *General Sciences* included an ultrafast x-ray source for femtosecond dynamics; novel coherent terahertz and infrared source using a laser wakefield accelerator and applications; compact coaxial d-d neutron generator and moderator research; foundations for a supernova acceleration probe; and a source of the far infrared radiation. Funds were allocated to *Energy Sciences* research in, for example, development of cool colored shingles; atmospheric chemistry and climate on extrasolar bodies; experimental constraints for habitability and spectroscopic signatures of life; indoor bioaerosol detection and quantification by polymerase chain reaction; aerobic bioremediation of landfills; and applying a coupled climate-land surface regional model to deduce trends in soil moisture from air temperature data. Efforts in the *Biosciences* areas included quantitative spatial and temporal resolution of multicellular interactions; pet ligands for the nmda receptor channel; high sensitivity *in-vivo* crosslinking method; and tracking proteins using visible-light and soft-x-ray microscopy. Research in the *Computing Sciences* areas included computational methods for electronic structure codes in materials science (ground state and excited state properties); numerical simulation of fuel cells; high-performance system area network for pc clusters; atomic-scale modeling of materials chemistry; segmentation of mammary-gland ductal structure using geometric methods; and adaptive file replication and coordinated transfer for data-intensive grid application. These projects provide a breadth of research capabilities that strengthen the Laboratory's future to address the needs of DOE and other sponsoring agencies.

Cooperative Research and Development Agreements (CRADAs)

Berkeley Lab conducts research in support of Cooperative Research and Development Agreements with industry where its unique expertise or facilities are of specific value. The 30 projects currently underway are in many fields, including efficient building systems, physics, chemistry, materials sciences, geosciences, and biology. A few larger CRADAs (above $200k) are:

- **EUV Limited Liability Corporation**. This research with the Advanced Light Source and the Materials Sciences Division involves x-ray optics and metrology for optical systems for extreme ultraviolet light lithography. The effort is conducted in partnership with Sandia and Livermore National Laboratories.
- **Capintec, Inc**. The goal of this project is to develop a line of compact nuclear medical imaging devices. These include a miniature imaging probe for interoperative detection of radionuclides to assist in cancer surgery, small compact cameras for detection of thyroid disease and breast cancer imaging, and a larger camera for cardiac and other nuclear medicine studies.

CRADAs typically directly support science aligned with DOE mission goals, are based on Laboratory competencies, and include topics such as plasma deposition, novel scintillators, photon imaging, advanced spectroscopy, cancer therapy, networking systems, electrochemistry, efficient lighting and windows, genomics and gene expression, x-ray optics, and microstructural analysis.

IV. INITIATIVES

INTRODUCTION

Berkeley Lab's role in the national laboratory system is based on its scientific leadership, core competencies, and research facilities. Berkeley Lab advances initiatives that hold promise for maintaining national leadership in science and technology in areas that support the Department of Energy's (DOE's) mission. Berkeley Lab's initiatives represent priority scientific thrusts that meet criteria of timely and forefront science, scope, and national scale and that mobilize institutional resources. Initiatives are provided for consideration by the Department of Energy, and in several cases, in conjunction with other sponsors as well. Inclusion in this plan does not imply DOE's funding approval or intent to implement an initiative.

Office of Science

Office of Advanced Scientific Computing Research

- Next-Generation Computer Architecture

Office of Basic Energy Sciences

- Molecular Foundry
- Advanced Light Source Science Strategic Plan
- Transmission Electron Aberration-Corrected Microscope (TEAM) at NCEM
- Linac-based Ultrafast X-ray Source (LUX)

Office of Biological and Environmental Research

- Genomes for Energy and the Environment: Genomes to Life
- National Sequencing Role for the Joint Genome Institute
- Neuroimaging with Advanced Molecular Probes
- Vadose Zone Studies

Office of Fusion Energy Sciences

- Heavy-Ion Fusion Integrated Beam Experiment

Office of High Energy and Nuclear Physics

- Supernova Astrophysics: SuperNova/Acceleration Probe (SNAP)
- Accelerators to Probe the Origin of Mass
- The Future of Neutrino Physics
- Gretina to GRETA (Gamma-Ray Energy Tracking Array)
- New Windows on the Microwave Universe

Workforce Development of Teachers and Scientists

- Workforce Development of Teachers and Scientists

Office of Energy Efficiency and Renewable Energy

- Solid State Lighting—Next-Generation Lighting Products

Office of Fossil Energy

- Geologic Carbon Sequestration

Office of Civilian Radioactive Waste Management

- New Science at Yucca Mountain

Office of Environmental Management

- Development of Site-Specific Conceptual Models
- Closing Water and Chemistry Budgets in Critical Supply Basins

Department of Homeland Security

- Reducing Chemical and Biological Threats in Buildings

Work for Others

- Advanced Controls for Energy Efficiency and Distributed Energy Systems (California Energy Commission with Office of Energy Efficiency and Renewable Energy)
- Systems Biology for Understanding Cancer (National Institutes of Health)
- Cell Design Institute (Defense Advance Research Projects Agency and Office of Basic Energy Sciences)
- Computational Cryo-Electron Microscopy (National Institutes of Health)
- Decoding Animal Genome Sequences (National Institutes of Health)
- High Throughput Structural Biology (National Institutes of Health)
- Molecular Machines for Maintaining Genomic Integrity (National Institutes of Health)

OFFICE OF SCIENCE

Office of Advanced Scientific Computing Research

Next-Generation Computer Architecture

In recent years scientific computing in the United States has been handicapped by its dependence on hardware that is designed and optimized for commercial applications. Typical scientific applications are now able to extract only 5 to 10 percent of the power of the United States supercomputers built from commercial Web and data servers. Lawrence Berkeley and Argonne National Laboratories have responded to this challenge with a proposal for a new program to bring into existence a new generation of computational capability in the United States that is optimal for science. The strategic white paper, "Creating Science-Driven Computer Architecture: A New Path to Scientific Leadership" envisions a new type of development partnership with computer vendors that goes beyond the mere evaluation of the offerings that those vendors are currently planning for the next decade. This comprehensive strategy includes development partnerships with multiple vendors, in which teams of scientific applications specialists and computer scientists will work with computer architects from major U.S. vendors to create hardware and software environments that will allow scientists to extract the maximum performance and capability from the hardware.

Currently the most dominant architecture for high-end computing is the IBM Power series, which accounts for 50 percent of the top 20 computers in the world, including the current NERSC Center 10 teraflop machine, now the most powerful unclassified supercomputer in the U.S. However, the Power architecture is not specifically tuned to the needs of the scientific market. A key component of this initiative is to enhance the architectures for scientific computing while, in parallel, implementing a system at Berkeley Lab by the end of 2005 that has at least twice the sustained performance of the Earth Simulator, at significantly lower hardware cost. The details of this approach are:

- **150 Teraflop System.** In collaboration with industry work to enhance current configurations in order to deploy a system with approximately 150 teraflop/s peak performance that will be able to sustain 40 to 50 teraflop/s sustained performance on at least several real scientific codes. Each of the 2,048 nodes will consist of eight "single core" Central Processor Units (CPUs) that provide double the memory bandwidth of the current CPUs, and will have their own dedicated caches. The CPUs will have a peak performance of roughly 8 to 10 gigaflop/s. The 150 teraflop/s system will have 16,384 CPUs, the maximum main memory bandwidth possible, 8,192 switch links, and 2.5 petabytes of shared, parallel storage in FY 2006. This system will have very high memory bandwidth, many interconnections, and very low interconnect latency.
- **Virtual Vector Architecture.** Work with industry to develop a new capability of Virtual Vector Architecture (ViVA), which harnesses the eight individual CPUs in a node into a single 60 to 80 gigaflop/s vector unit. ViVA will be implemented on the 150 teraflop system through software that will take advantage of current architectural features. It has the potential to further improve the performance of codes.
- **Future Processor Designs.** Building on experiences with the proposed 150 teraflop system and ViVA, cooperatively work with industry to further enhance future processor designs. Teams of DOE computational and computer specialists will work with processor designers toward the goal of further improving memory and interconnect bandwidth. The goal will be to field a petaflop/s (peak) computer capable of 20 to 25 percent sustained rates on diverse application by 2009.

This approach can take technology due for implementation in CY 2005, and expand its capability in multiple ways as an immediate and highly reliable enhancement to the scientific computational power of the DOE science community. The system will be built on CPUs which will run at approximately 2+

gigahertz, and a high throughput switch. At that rate, each CPU is theoretically capable of 8 to 10 gigaflop/s. Using new functionality and special packaging will allow the system to achieve a much higher sustained percent of peak on true scientific codes from multiple disciplines.

The proposed 150 teraflop machine can be delivered in FY 2006. The system requires approximately six megawatts of power for the computer and peripherals, and requires 1,700 to 2,000 tons of cooling. The entire system can be located in existing laboratory space.

Next-Generation Computer Architecture
Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	15.2	30.4	143.8	144.6	146.0	480.0
Equipment	4.1	7.7	20.5	23.5	16.5	72.3

* Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KJ). Operating costs are computer lease payments, equipment costs are for computer support infrastructure.

Office of Basic Energy Sciences

Molecular Foundry

The Molecular Foundry is an Office of Basic Energy Sciences Nanoscale Science Research Center, advancing the Department of Energy's role in the National Nanotechnology Initiative, and consistent with Department guidance and its two reports: *Nanoscale Science, Engineering and Technology Research Directions*, and *Complex Systems: Science for the 21st Century*.

The Molecular Foundry will be a major basic research user facility in nanoscience, stressing the conjunction of both "soft" and "hard" nanostructures and the fabrication of multicomponent functional systems made up of these two types of building blocks. Its centerpiece will be an array of six unique, state-of-the-art facilities in the design, synthesis, and characterization of nanostructures. These facilities, along with an associated scientific and technical staff, will be available to users from academic, governmental, and industrial laboratories across the country. The Molecular Foundry will also serve to educate and train hundreds of undergraduate and graduate students and postdoctoral fellows. Finally, it will serve as a "portal" to the Berkeley Lab user programs of the Advanced Light Source (ALS), the National Center for Electron Microscopy (NCEM), and the National Energy Research Scientific Computing (NERSC) Center, all of which have strong programs to support research in nanostructures.

The foundry will have a substantial internal research program, a component that will be essential to the viability of a productive, useful, and continually updated external collaborative program. The internal research activity will exploit the breadth of interests and experience of investigators now at Berkeley, or to be recruited. It will have two primary foci. The first will be studies not only of conventional "hard" nanocrystals, tubes, and lithographically patterned structures—but also of nanometer-sized "soft" materials, such as polymers, dendrimers, DNA, proteins, and even whole cells. (Cells are, of course, of micron dimensions, but their functions are based on systems whose components function at nanometer dimensions.) The second research focus will be the design, fabrication, and study of multicomponent, complex, functional assemblies of these hard and soft nanostructures.

The Molecular Foundry will be housed in a new state-of-the-art building adjacent to the National Center for Electron Microscopy and near the principal materials sciences area. It will be designed as a user facility to support multidisciplinary research in fields including materials science, physics, chemistry, biology, and engineering.

Working at the nanometer scale is not simply doing "micron-level" work with smaller objects. Nanoscience phenomena, synthetic approaches, and characterization techniques are far more sophisticated, and innovative research is a far greater challenge. Through the facilities of the Foundry, and the availability of its trained scientific staff for collaboration and teaching, this challenge can be made tractable to a far broader section of the scientific community.

Molecular Foundry Resource Requirements ($M)*

	2003	2004	2005	2006	2007	2008	Total**
Operating	3.0	3.0	3.0	20.0	24.0	24.0	77.0
Construction and equipment	6.8	35.0	32.0	9.8	0.0	0.0	83.6

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KC).
** Includes prior year funding.

Advanced Light Source Science Strategic Plan

The soft x-ray and vacuum-ultraviolet (VUV) range of the spectrum offers tremendous promise for scientific advancement, as reported in February 2000 by the Basic Energy Sciences Advisory Committee Subpanel Review of the Advanced Light Source (ALS), which commented on the outstanding research and user support program being conducted at the ALS. For the past several years, the ALS user community has been developing key research directions, which address the scientific promise of the ALS.

To ensure development of this science and full utilization of the ALS, the research community and the Laboratory have collaborated to construct an ALS Strategic Plan that responds to the recommendations from workshops, the ALS Science Policy Board, which advises the Laboratory, and the most recent review of the ALS by a panel of the Basic Energy Sciences Advisory Committee (BESAC). Based on a series of semiannual planning meetings involving ALS management and representatives of the user community, the current plan provides for the installation of the full complement of insertion devices (undulators and wigglers) in the ALS storage ring, and full instrumentation of the insertion-device and superbend beamlines.

In addition, since the ALS was one of the first third-generation machines to be designed, its performance will be outstripped by later, more advanced machines. Accelerator and insertion device technology have significantly changed since the conception of the ALS, and to remain competitive we are planning the ALS Upgrade to enhance the performance of the ALS to meet and then set the new standard.

A top priority is to effectively accommodate the needs of the Advanced Light Source user community. These needs include laboratories that support research at the ALS beamlines, offices, and 4–10 instrumentation staging areas. The number of users at the ALS has seen a several fold increase in recent years to over 1,600, and—just with the completion of currently funded beamlines—is expected to increase to over 2,000 users by FY 2004. By the end of the decade, the ALS will serve about 2,500 users. An upgraded user facility supports the main recommendation of the BESAC Subpanel Review of the ALS "to support the ALS plan to have a new building adjacent to the machine to have more office space for users and laboratories for sample preparation and experiment staging." The scope of the proposed facility includes laboratories to support users at the planned 55 beamlines, and to advance research in disciplines in addition to the nanoscience area.

Offices will be needed for ALS scientists and for ALS experimental systems support, beamline/optical systems, and endstation design personnel. In addition, conference rooms and user center support and training areas will be provided. The facility will be located immediately adjacent to the ALS and will replace several existing substandard facilities constructed primarily during World War II. These wood frame structures are potential fire hazards with poor structural, mechanical, and electrical systems.

Rather than being a static document, the strategic plan is evolving over time as priorities shift to take into account the changing needs of users from industry, academia, and government laboratories, and new scientific opportunities. As validated by our strategic planning process, the high-priority aspects of the plan are reflected in recent proposals for experimental facilities that enable the ALS to address forefront scientific areas:

- **ALS Upgrade.** Exploitation of the high brightness of a third-generation source translates into three areas: (1) high resolving power for spectroscopy, (2) high spatial resolution for microscopy and spectromicroscopy, and (3) high coherence for many experiments. Substantial improvements in brightness and current have always been quite feasible, but they incur the penalty of a much reduced lifetime totally unacceptable to our users. In top-off mode, injection would be quasi-continuous, and so the lifetime objections disappear. Significant brightness improvements can be realized in the core soft x-ray region by going to top-off operation with higher average current, reducing the vertical emittance and beta function, and installing small gap permanent-magnet or superconducting insertion devices. One-to-two orders-of-magnitude improvement in brightness can be had in the soft x-ray range, and the proposed upgrades extend the high energy range of the undulator radiation beyond the current limit of 2,000 eV.
- **Magnetic and Polymer Nanostructure Research.** The study of magnetism and the structure of polymers in thin films and at surfaces at length scales as short as 20 nanometers is now possible using a newly developed photoemission electron microscope (PEEM2) in combination with the spectroscopic techniques of x-ray magnetic circular dichroism (XMCD) and near-edge x-ray absorption fine structure (NEXAFS), respectively. While this instrument can address many important problems in magnetism, such as the origin of exchange biasing of ferromagnetic layers by antiferromagnetic substrates, there is a clear need for even higher spatial resolution to address important problems in both fields. A new R&D effort will establish at the ALS a state-of-the-art microscope facility with nanometer resolution and magnetic imaging capability. The facility will include an elliptically polarized undulator (EPU), a new beamline optimized for this work, and an aberration-corrected microscope, PEEM3.
- **Femtosecond (fs) X-rays.** An important new area of research in chemistry, physics, and biology is the application of x-ray techniques to investigate structural dynamics associated with ultrafast chemical reactions, phase transitions, vibrational energy transfer, and surface dynamics. The fundamental time scale for these processes is a single vibrational period (~100 femtoseconds). Based on the recent successful demonstration on a bend-magnet beamline at the ALS of the time-slicing method of producing femtosecond x-rays, this R&D effort establishes an in-vacuum, narrow gap undulator beamline at the ALS optimized for the next-generation of high-brightness femtosecond x-rays for time-resolved structural studies of solution reactions, surface processes, and protein dynamics. This research and development is directly relevant to a possible new national user facility for femtosecond structural dynamics.
- **Ultrahigh Resolution Spectroscopy Beamline.** The high productivity of the heavily oversubscribed beamline 10.0 for high resolution photoemission has led to a proposal for a new beamline dedicated to ultrahigh resolution (meV) spectroscopy. The beamline would have a low energy (<100 eV) EPU and monochromator with two innovative end stations, one dedicated to meV-resolution photoemission, and one to high resolution inelastic scattering. The primary program would be directed towards the study of highly correlated materials.

- **CIRCE—Coherent InfraRed CEnter.** Intense broadband sources over the traditionally difficult wavelength range of 100 microns to a few millimeters will enable a number of exciting scientific applications. These include low-energy excitations in highly correlated materials, nonlinear dynamics in novel materials, and new medical imaging techniques. We are exploring options for a small dedicated synchrotron for producing coherent far-infrared/terahertz radiation. Experiments at the ALS and at other facilities have demonstrated that coherent terahertz emission produces very high powers, have verified the regime of stability for coherent emission in a storage ring, and have used coherent synchrotron radiation in a ring for measuring the Josephson plasma frequency in a high-temperature superconductor. The ring design will capitalize on existing ALS infrastructure, such as an existing injection system and user support facilities. The new ring will extend and complement the scientific capabilities at the ALS.

  Also in conformance with the recommendations of the BESAC panel, the plan envisages aggressive exploitation of the superbend beamlines and the extended spectral range they provide.

- **Microbeams for Materials and Earth Sciences**. The ALS has demonstrated the ability to provide sub-micron focused beams of intermediate-energy x-rays from bend magnets for spatially resolved x-ray diffraction and absorption. The proposal is to extend this capability by establishing superbend facilities for microbeam x-ray diffraction for materials sciences, microbeam extended x-ray absorption fine structure (EXAFS) spectroscopy for earth sciences, and microbeam powder diffraction.
- **Center for High Pressure**. A superbend beamline dedicated to high-pressure research will take advantage of the combination of high-pressure/high-temperature techniques and synchrotron radiation, which together provide a powerful means of studying condensed matter. The beamline will give excellent performance to over 40 keV. Density is one of the most fundamental characteristics of a solid, and many new phenomena (superconductivity, phase transitions, metal/insulator transformations) are observed as density is varied through the application of pressure. Condensed-matter theorists can now predict many-body properties as a function of the density, and critical tests of these emerging theories are needed. In solid-state chemistry, there is a huge unmet need for an improved understanding of how particular solids form, when a high-energy phase will be metastable, and what the mechanisms are for structural transformations. In geophysics, fundamental problems bearing on the dynamics of planetary interiors and the geological history of volatile species can be addressed using high-pressure/high-temperature techniques. This proposal brings together users from University of California campuses and national laboratories as the core of a research community of diverse users, all of whom share a common need for a synchrotron x-ray beamline in support of high-pressure science on the West Coast.

The six-year budget plan below does not support those elements of the strategic plan that are based on user proposals (whether from within the Laboratory or outside). The budget plan does assume additional staff so that the facility takes over responsibility for the operation of the BES beamlines over a three-year period from FY 2005 through FY 2007.

Advanced Light Source Science Strategic Plan Resource Requirements ($M)*

	2003	2004	2005	2006	2007	2008	Total
Operating	33.2	34.2	38.2	40.6	42.9	44.2	233.3
Equipment	4.2	4.2	5.3	5.4	5.6	5.7	30.4
ARIM/AIP	2.2	2.5	7.6	6.7	5.8	6.0	30.8
WFO	1.2	1.2	1.2	1.2	1.2	1.2	7.2

*Preliminary estimate of total Berkeley Lab Budget Authority (B&R Code KC) and Work for Others (WFO).

Transmission Electron Aberration-Corrected Microscope (TEAM) at NCEM

Electron microscopy is on the brink of a revolution based on major recent advances in electron optics, detectors, stage design and computing power. These advances make it possible to overcome the fundamental limitations currently imposed by lens aberrations.

Under the leadership of Berkeley Lab's National Center for Electron Microscopy (NCEM), the five BES centers for electron beam microcharacterization, located at Berkeley, Argonne, Brookhaven and Oak Ridge National Labs and the University of Illinois are prepared to develop the next generation Transmission Electron Aberration-corrected Microscope (TEAM). Collectively, these centers have the scientific expertise and the supporting infrastructure to carry out such a project and to ensure that the resulting instrumentation benefits the entire scientific community. The TEAM instrument's unique ability to characterize nanomaterials with unparalleled resolution is of central importance to the current national effort in nanoscience, and supports the co-location of this project with DOE's nanoscience facilities. In particular, the location of the first TEAM instrument adjacent to Berkeley Lab's Molecular Foundry will be of great benefit.

In the aberration-corrected approach to atomic resolution, a new field emission instrument will be developed, optimized for 0.5-angstrom resolution in real-time, using both, phase- and Z-contrast imaging techniques. The objective lens geometry will maintain sufficient space in the sample area to allow high-angle tilting for nanocrystal structure refinement, three-dimensional reconstruction, and for in-situ manipulation and measurement during atomic-resolution observation. This instrument will also include the ability to perform energy-filtered imaging, holography, highly localized spectroscopy with sub-eV spectral resolution, and fast, position-sensitive nanodiffraction.

A fully aberration-corrected microscope will offer unsurpassed electron optical performance, with the ability to obtain the atomic structure, composition or bonding with high precision and atomic spatial resolution. The removal of aberrations also makes it possible to increase the focal length of the electron lens while maintaining performance. The additional space allows new sample geometries for three-dimensional tomography, in-situ experimentation, or the addition of new detectors. With atomic-resolution in a wide-gap lens, precise and quantitative imaging techniques can be applied to many exciting materials characterization problems that are currently inaccessible to experiment.

The TEAM instrument will be designed as a platform for future development of a variety of instruments that will be specialized for different purposes such as wide-gap in-situ experimentation, ultimate spectroscopy, field-free high resolution magnetic imaging, ultrafast high resolution imaging, diffraction and spectroscopy, and other extremes of temporal, spectral, spatial or environmental conditions.

Within this cooperative effort, NCEM plans to integrate electron-optical instrumentation with a forefront effort in computing to develop unique new capabilities for quantitative atomic scale imaging. These new capabilities will include:

- Nanocrystallography: atomic structure determination and refinement from individual nanocrystals and defects;
- Real-time in-situ observation of atomic-level mechanisms and dynamics;
- Three-dimensional reconstruction at atomic resolution; and
- High-resolution spectroscopy from individual nanostructures.

Advanced tools such as these will provide opportunities for groundbreaking research and aid in the development of advanced materials and the discovery of new phenomena.

Recent experience with NCEM's One-Angstrom Microscope has shown that at resolution levels near and below one angstrom, the sample itself becomes the limiting factor. Quantitative imaging and spectroscopy at this level of resolution require methods for preparation of uniformly thin, artifact-free samples, often in geometries designed for specific experiments. These methods must be reliable and applicable to the vast variety of heterogeneous and composite materials typical for advanced technologies. NCEM will launch a major program in this area with specialized instrumentation such as microlithography, a focused ion beam instrument, dedicated personnel, and laboratory space. This facility will be made broadly available to the collaborative user community and is expected to contribute greatly toward the goal of fully quantitative electron beam microcharacterization. To prepare for new ways of conducting research, NCEM will further develop its link to the other DOE microcharacterization facilities in an electronic "collaboratory," a laboratory in cyberspace that serves as a gateway to the combined instrumentation and expertise available at all five member institutions. Researchers will be able to collaborate via internet link with NCEM or any of the other facilities, using their combined expertise and instrumentation in a new platform-independent setting.

TEAM Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	3.0	4.0	4.0	1.0	1.0	13.0
Equipment	0.0	0.0	0.0	6.0	6.0	12.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KCO2).

Linac-based Ultrafast X-ray Source (LUX)

The use of femtosecond optical lasers has revolutionized the study of many phenomena in solid-state physics, chemistry, and biology in the last 30 years. For example, invention of the mode-locked, continuous wave (cw) dye laser in 1971 enabled the direct observation of extremely short-lived transition states—intermediate conformations between reactant and product species that have, in some cases, a lifetime on a time scale of a vibrational period, 100 femtoseconds, or less. The scientific significance of transition-state chemistry was recognized with the award of the 1999 Nobel Prize in Chemistry to A.H. Zewail. Many other examples of the importance of femtosecond optical studies exist—from laser-driven, solid-solid phase transitions to the study of photochemistry in biological systems—and clearly this area has grown into one of the most dynamic in modern science.

Although great progress has been made with optical spectroscopy, which probes extended electronic states, the information most needed is the motion of atoms. This is where x-ray techniques excel. X-ray diffraction provides direct three-dimensional information, and x-ray absorption provides a radial distribution function of atomic positions. X-ray spectroscopy adds details of the electronic configuration necessary to build complete pictures of complex interactions. Combining these techniques with a 20 to 50 femtosecond x-ray source will revolutionize many of the fields in which ultrafast optical techniques are used. Since 1993, Berkeley Lab has worked toward becoming the leading center worldwide in structural dynamics using x-rays. Several sources have been built at the ALS based on Thompson scattering and on the interaction of an intense laser beam with the ALS electron beam. These sources have been used to study a variety of dynamics, in particular the dynamics of ultrafast melting. While these studies have been successful in understanding solid-state dynamics in perfect single crystals, the U.S. scientific community will require a much more powerful broadband x-ray source in order to address the wide range of science currently studied using optical techniques.

Together with the Stanford Synchrotron Radiation Laboratory (SSRL) and two European light sources (BESSY, in Berlin, and the Swiss Light Source) Berkeley Lab sponsored a workshop in April 2002 that brought together the existing ultrafast optical community and the emerging ultrafast x-ray community. The time regime from 50 picoseconds to a few tens of femtoseconds was the core focus area for this workshop, which was intended to define scientific highlights and directions for the use of the x-ray techniques, to promote cross-fertilization of ideas between the two communities, and to define the source characteristics required for particular classes of experiment. This workshop has led to a survey of the compelling scientific opportunities and an understanding of how the many possible x-ray sources (laser-based systems, slicing at synchrotrons, FELs, ultrafast linacs, energy-recirculating linacs, etc.) best enable that science.

From these studies, the design of a Linac-based Ultrafast X-ray Source (LUX) has been carefully refined to provide a most compelling facility for a broad range of ultrafast x-ray science. The facility provides multiple tunable beamlines for simultaneous user groups, operating over a photon energy range of 20 eV to 12 keV, and with sophisticated laser and diagnostic systems. LUX will provide an increase in flux of more than 10^6 compared to our present ALS ultrafast laser-slicing beamline and up to twenty simultaneously operating experimental stations. The proposed facility is based on several robustly developing new technologies: (1) a high-brightness photo-gun to produce intense, short pulses of electrons, (2) a superconducting linac to boost electrons to high energy, (3) a recirculator to direct electrons several times through the same linac structure, (4) radiofrequency “crab” cavities to kick the electron beam to produce a longitudinal tilting of the beam, (5) optical pulse compression, (6) cascaded harmonic generation in free-electron lasers, and (7) multiple short-pulse laser systems with temporal and spatial profiling capabilities. All of these technologies are well understood, and many are currently undergoing vigorous development. For example, the superconducting linac is based on technology built for the Tera Electron Volt Energy Superconducting Linear Accelerator (TESLA) high-energy physics program in Hamburg, Germany, and is commercially available. Radiofrequency photo-guns are in use at a number of laboratories developing free electron lasers (FELs). By using an assembly of these technologies, we can provide an ultrafast x-ray facility with unprecedented performance, in the environment of a national user facility.

The LUX facility we are proposing to build at Berkeley Lab and x-ray FELs, such as the Linear Coherent Light Source at SSRL, complement one another. The linac-based source will provide outstanding performance compared to presently available sources. The linac-based source also has the advantage of absolute synchronization of laser pump and x-ray probe, and a relatively short pulse length of 20 femtoseconds. Self-amplified spontaneous emission (SASE) x-ray FELs, on the other hand, will provide the ultimate single-pulse hard x-ray flux—some 1,000 times higher still than the Berkeley Lab proposal. Consequently, a sound national program would address the needs of this emerging field with a linac-based national user facility while continuing the development of SASE hard x-ray FELs in parallel to provide the route to even higher performance in the future.

Berkeley Lab's Accelerator and Fusion Research, Chemical Sciences, Materials Sciences, and Advanced Light Source Divisions have joined forces to produce a feasibility study report. The scientific need and the project proposal have been presented to the Basic Energy Sciences' subcommittee on 20-year Facilities Roadmap, and their recommendations to the Office of Basic Energy Sciences were highly encouraging. Details of the science to be performed, and the machine design to meet scientific needs, are currently being refined.

Linac-based Ultrafast X-ray Source (LUX)
Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	6.0	8.0	6.0	0.0	0.0	20.0
Construction**	0.0	0.0	3.0	25.0	50.0	78.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KC).
**Additional out-year construction resources being estimated

Office of Biological and Environmental Research

Genomes for Energy and the Environment: Genomes to Life

Berkeley Lab's flagship program under *Genomes for Energy and the Environment: Genomes to Life* (GTL) strives to understand how bacteria and other microorganisms respond to and survive external stresses. This systematic, systems-based approach offers myriad benefits to the Office of Science and the nation: decades and millions of dollars saved in bioremediation; a foundation of fundamental research with public health and counterterrorism applications; and true progress toward engineering cellular functions. This program drives the development of a resource to accept and serve quality-controlled and analyzed data to a broad scientific community interested in microbial physiology and ecology. And as it fulfills its potential, it necessitates large-scale, collaborative experimental facilities to image and measure all aspects of microbial physiology.

In our next phase of research, we will integrate and extend our capabilities by initiating a true national resource in systems biology. This resource will be comprised of three research centers, with three integrated foci:

- To characterize and model the dynamic composition, structure, and function of microbial molecular machines;
- To develop the science of metabolomics with an emphasis on microbial systems pertinent to environmental metal immobilization; and
- To create a definitive core for warehousing, analyzing, and developing microbial physiological models.

These three research centers will be shaped by our collaborations with other laboratories and universities, and by the needs and scope of future proposal calls.

Characterization of Microbial Molecular Machines

Many microbial processes of key DOE interest, such as cell signaling, nitrogen fixation, carbon sequestration, and breakdown of hydrocarbons, are carried out by molecular machines that operate as specialized assembly lines. Molecular machines are protein/protein and protein/nucleic acid complexes that respond to altered environments by changing their activities, constituent polypeptides, covalent modifications, and subcellular locations. If we are to learn how to fully interpret genome-sequence information and gain the power to modify the biochemical activities of microbes, we must understand the rules that govern the function of their constituent molecular machines, protein/protein partner choice, subcellular location, and changes in phosphorylation and other modification states.

Berkeley Lab has major scientific strength in imaging and biophysical/biochemical characterization of protein complexes and molecular machines. Combined with our developing high-throughput capabilities to purify, identify, and characterize the modification states of all protein complexes in the cell, we are building towards an integrated capability to characterize and model the changing composition and structure of protein complexes in microbes under many environmental conditions. Such an integrated program depends on specialized scientific teams exchanging information in a rapid, coordinated, and robust fashion, and this approach implies a radical change in the ways scientists normally investigate molecular machines.

Our medium-term goal is to develop new ways of investigating molecular machines, and to be able to completely characterize the molecular machinery repertoire of a given bacterium. Our strategic goal is to develop a facility that can comprehensively analyze the molecular machines in several bacterial species per year, and whose technology can be applied to other organisms as well. Developing such a facility will use Berkeley Lab's unique combination of strengths in biology, biochemistry, chemistry, computer science, engineering, and microbiology.

This facility for the "Analysis of Molecular Machines as a Function of Cellular Stress" will build on Berkeley Lab's world-class capabilities in production, imaging, and manipulation of molecular machines, and will be based on high throughput application of numerous complementary analysis techniques to a microbe's constituent molecular machines, and produce quantitative data that will feed directly into computer simulations and modeling of molecular machines.

Refining Metabolomics

The emerging field of metabolomics (the system-wide analysis of an organism's metabolite profile) is important for understanding how organisms respond to environmental stress and evolve to survive in new situations. The broad objective of this proposal is to develop new methods for metabolome analysis, with a focus on systems pertinent to environmental metal mobilization. The research would develop mass spectroscopy and nuclear magnetic resonance (NMR) methods for elucidating sulfate and phosphate conjugation pathways, as well as the effects of environmental stresses on those pathways. The techniques developed in this project can be widely applied to systems-level analysis of metabolic pathways at the level of individual metabolites.

Core for Warehousing, Analyzing, and Developing Microbial Models

Computation and data infrastructure is the spine that supports and integrates every aspect of a comprehensive systems biology study. The various Genomes for Energy and the Environment: Genomes to Life projects are already producing diverse and complex data sets, ranging in scope from DNA to protein, to metabolites, and to whole cell populations. However, we lack the overarching computational tools required to synthesize these data into a more comprehensive understanding of how microbial systems work. Additionally, we already have a pressing need for a central data repository, bioinformatics, and modeling resource. If these activities remain at disparate sites in disparate forms, much of the experimental data will be poorly utilized or lost.

We propose to create the collaborative data infrastructure necessary for such a program. This central facility for storing and analyzing data will become a focus point not only for researchers to donate and evaluate their results, but also for those interested in the data analysis itself. The large data sets would be suited to researchers developing supercomputing tools for data mining and simulation. This infrastructure also would help fuse DOE efforts by providing data interchange and relational standards for current and future DOE initiatives.

A dedicated effort towards improved computation and data infrastructure would quickly yield results directly pertinent to the DOE mission; within one to two years, data analysis could identify key molecules and processes in areas of microbial function such as waste decontamination, carbon sequestration, and other important model cellular pathways. The infrastructure would further maximize DOE efforts by providing logical guidance on which proteins, experimental measurements of proteomics data, and molecular complexes will be most important for other projects to focus on. In short, the computation and data infrastructure would quickly serve not only a valuable scientific resource, but also as a showcase for the progress of Genomes for Energy and the Environment: Genomes to Life, and other programs. The infrastructure would become a "National Library for Microbial Physiology and Ecology," as both a flagship data bank and a focused research center.

Our initial focus will be a project entitled "Deduction of Pathways from Data: Theory, Computation, and a Data Infrastructure," a four-part project focused on pathway inference in prokaryotes. The project's first part is the creation of a standard data repository, the foundations of which can be found at http://tayma.lbl.gov/perl/biofiles. Using those standardized data sets, we will next develop a statistical quantitation and classification of data. This involves the development of new data models and intensive, computationally efficient algorithms. Third, we will compile and create network prediction tools to reverse-engineer a network design appropriate for Genomes for Energy and the Environment: Genomes to Life's diverse data types. Finally, we will develop simulation and analysis tools of varying scales and abstractions, and develop methods for principled comparisons between models and data.

Genomes for Energy and the Environment: Genomes to Life
Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating/Equip.	4.2	5.4	6.6	6.8	7.0	30.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KC).

National Sequencing Role for the Joint Genome Institute

In partnership with Livermore and Los Alamos national laboratories, Berkeley Lab will continue its scientific and management participation in the Joint Genome Institute (JGI). Established as the DOE component of the International Human Genome Project, the JGI has achieved remarkable efficiency in sequencing genomic DNA while achieving its goal of the completion of the high quality DNA sequence of human chromosomes 5, 16, and 19. These efficiencies have also made it possible to produce genomic sequence of many different animal and microbial species, revolutionizing biological research by opening the field of comparative genomics and greatly enabling functional genomics.

The large DNA sequence data sets developed at the JGI are the foundation of this revolution. Scientists can now exploit computational analysis of the instruction sets for key species in the biosphere and evolution. This is a unique niche for a production sequencing facility. While other federally supported facilities are focused on human disease and health-based biology (largely due to their NIH funding), the JGI will focus on the non-human biosphere. In particular, JGI will sequence and analyze microbial species for the Genomes for Energy and the Environment: Genomes to Life project. The capability to sequence entire microbial communities consisting of multiple species and genera, without the necessity of isolating and culturing the organisms, will substantially increase our understanding of the life processes in a wide diversity of biological environments. These environments can be natural or the result of human activity such as energy production.

It has become clear that this high-throughput sequencing and analysis capability can advance the broader scientific community as well as DOE missions. Therefore, sixty percent of the JGI’s sequencing capacity of over 1 billion base pairs per month will be available through the Community Sequencing Program to all scientists as a service as determined by scientific peer review of nominations for DNA sequencing targets. The remaining sequencing capacity will continue to address DOE research on microbes for energy and the environment. Example mission-relevant areas include waste remediation, carbon management, and energy production. The switch to a national resource mode will begin in FY 2004.

Community Sequencing Program projects begin with a proposal from a researcher to sequence DNA from an organism or group of organisms. Proposals will be evaluated by the Proposal Study Panel, a group of experts from the scientific community. The recommendations of the Panel are considered by the JGI Scientific Advisory Committee and are evaluated for technical issues by the JGI's Scientific Support Group. Once sequencing is underway, data will be made available to the entire scientific community in accordance with the JGI's data release policy. At the completion of a project, the JGI will make the assemblies, gene annotations, and analyses available to the community at large.

This evolution to a national resource will serve the needs of other federal agencies and consortia of university scientists such as occurred with the *Ciona* project. The ongoing *Xenopus* sequencing project at the JGI is a continuation of this type of collaboration. The Department of Agriculture and the Environmental Protection Agency are collaborating with JGI on the sequencing and analysis of crop pathogens and environmental indicators. We expect this to continue and expand.

By turning to the sequencing challenges of a variety of organisms, the JGI can greatly enrich the genomic data sets available to the scientific community. This will place DOE in the leadership for understanding quantitative and systems biology. With the completion of DOE’s leadership sequencing role in the Human Genome Project and the production and efficiency gains during FY 2002–2003, a new funding initiative is not required.

Neuroimaging with Advanced Molecular Probes

This initiative will exploit the Laboratory’s strengths in nuclear medicine to develop new radiotracers and fluorescent tracers to probe brain function and disease through non-invasive imaging. New Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI), methods, instrumentation, and experiments will be undertaken for high resolution structural and functional brain data in humans and animals.

The Initiative will extend DOE’s development and use of radioisotopes for medical applications and their substantial success in applications for cardiac disease evaluation and cancer detection. Modern molecular and cell biology methods will be coupled with the strengths of the tracer techniques. For example, techniques such as green fluorescent reporter gene uses in tissue and cell biology can be expanded substantially by use of other genes and relevant fluorescent and radiotracer probes. In addition, there is a need for target-specific ligands for receptor proteins peculiar to neuroscience studies as well as to research on cancer and atherosclerosis. Both neuroscientists and molecular cell biologists have needs for a new neuroimaging technical resource that can supply the probes and imaging instrumentation for critical experiments.

Validation of the specificity of new probes involves kinetic biodistribution studies, binding studies, evaluation of metabolic products, and other cell and tissue analytical approaches. These capabilities and services will be an essential feature of the proposed resource that is based on Office of Science research accomplishments and that will attract both industry and NIH-supported research. Many of these methods depend on imaging the trafficking of labeled cells, which requires new research in chemistry to develop the probes and improved instrumentation to image them. Part of the rationale of the proposed neuroimaging resource includes the capability to non-invasively image the distribution of new tracers using emission tomography and light imaging. This is an area in which new instrumentation technologies will complement the probe development. Sensitivity and resolution improvements in animal and human subject imaging are planned with new scintillators that have sufficient timing and energy resolution to permit full three dimensional time-of-flight measurements. This will become possible through the development of a new class of scintillators that is based on wide-gap semiconductors activated with certain impurity atoms, and through the development of image reconstruction algorithms that make efficient use of this new information.

Immediate scientific problems in neuroimaging that would benefit greatly from these approaches and could be addressed by the proposed program include:

- Applying measurements of brain structure (using MRI at 1.5 telsa) and neurochemical changes in the cholinergic system to groups of normal aging individuals in an effort to predict the development of cognitive decline and Alzheimer's disease.
- Detection of amyloid deposition in the brain of normal individuals and those with Alzheimer's disease. This project will require considerable radiochemistry input, but if successful can interact with the above project to develop methods of detecting pre-symptomatic disease.
- Evaluating relationships between regional neurochemical changes and brain activity through a number of approaches. One approach is to perturb chemical systems pharmacologically, and measure changes in receptor occupancy with PET and brain activation with functional MRI to define how neurochemical systems modulate cognitive processes. Another approach is to study groups of older subjects with cognitive loss using neurochemical tracers to detect relationships between cognitive changes and neurochemical changes. The variability in neurochemistry that occurs in aging can help reveal how aging, cognitive change, and neurochemistry are related.
- Studies of animal models of disease can be performed to measure neurochemical and biochemical effects of disease and treatment. For example, animal models of Parkinson's disease can be followed for changes in the dopamine system, and response to gene therapy using dopamine tracers can be monitored. Similar animal models of other neurodegenerative diseases can be developed and monitored with structural and functional MRI, PET, and MR spectroscopy.

The proposed resource would include core programs in radiotracer and fluorescent tracer development that would coordinate the radionuclide chemistry from four centers (Berkeley Lab, UC San Francisco, UC Davis, and Stanford) and would collaborate with individuals developing fluorescent probes and methods of targeting cells. The physical resources would include high resolution imaging systems for animals and human subjects. These technological advances will be closely coupled to a joint Berkeley Lab/UC Berkeley neurosciences initiative whose theme will be the measurement of changes in brain structure and function in aging and neurodegenerative diseases. Berkeley Lab and UC Berkeley are uniquely poised to work together to take advantage of the new resource. A high field, 4 tesla MR magnet on campus, with an outstanding group of neuroscientists and engineers experienced in the functional MRI study of neural activity and cognition, is a major UC Berkeley strength that will be synergistic with the long Berkeley Lab tradition of excellence in radiotracer development and PET technology.

Neuroimaging with Advanced Molecular Probes
Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	1.0	1.0	1.0	1.0	1.0	5.0
Equipment	4.0	2.0	1.0	0.0	0.0	7.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KP with WFO/NIH).

Vadose Zone Studies

Supporting DOE in its mission to remediate, restore, and close contaminated sites requires fundamental and applied vadose zone studies as a basis for selecting the most effective and most cost-efficient technology. To address this challenge, Berkeley Lab proposes to establish a multidisciplinary *Center for Fundamental and Applied Vadose Zone Studies.* Berkeley Lab's experience in conducting and integrating vadose zone studies and its nonalignment with a major DOE contaminated site enables it to objectively evaluate alternative vadose zone characterization, modeling, and remediation approaches and technologies. This work builds on the 20 years of experience gained from working in the vadose zone of Yucca Mountain as part of the nuclear waste disposal program. As a result, Berkeley Lab has a unique core and base of expertise to draw upon. The main goal of the Center is to provide DOE and other government agencies with the scientific and technological basis for making critical decisions regarding vadose zone problems of scientific and practical relevance, such as the characterization and prediction of contaminant fate and transport, assessment of remediation alternatives, including natural attenuation and bioremediation, optimization of cleanup strategies, and long-term stewardship. This goal is achieved through a combination of the following types of activities:

- **Fundamental and applied research** will be conducted to address key scientific and technical questions concerning vadose zone processes relevant to contaminated sites at DOE and other federal, state, and local facilities. The research will advance the identification and characterization of these processes, and improve the prediction of natural attenuation and design of active remediation under complex vadose zone conditions.
- **Comparative studies** of different site characterization methods (including measurement and monitoring techniques), modeling approaches, and remediation technologies will be performed to assess their appropriateness, performance, and reliability for a certain environmental setting or a specific DOE site. These studies will result in recommendations that DOE can select and prioritize. The Center's recommendations regarding vadose zone technologies will be aligned with DOE's schedule for cleanup and closure of DOE's contaminated sites.
- **Technical assistance** for the solution of specific short-term and long-term environmental problems will be offered, providing support for characterization, modeling, cleanup, and site-closure activities. Other services to government agencies and the scientific community will promote information exchange, professional education, and technology transfer.

These activities will be tailored to the needs of DOE, specifically in supporting decisions regarding cleanup and long-term stewardship of DOE's organic, radioactive, or mixed-waste contaminated sites, but also in activities on carbon sequestration and gas-hydrates. A significantly improved understanding of vadose zone processes and recommendations of modern vadose zone technologies will allow DOE to better assess the environmental risk to the public, select the most effective and efficient remediation technology, confirm the potential for bioremediation and natural attenuation, and thus accelerate site-closure schedules with the associated significant cost reductions.

Vadose Zone Studies Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	1.0	2.0	3.0	4.0	4.5	14.5

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KC).

Office of Fusion Energy Sciences

Heavy-Ion Fusion Integrated Beam Experiment

Several national review committees, including those of the National Academy of Sciences and DOE's Fusion Energy Sciences Advisory Committee, have endorsed the potential of heavy-ion accelerators as drivers for inertial fusion energy. The Heavy Ion Fusion program at Berkeley Lab, as a part of the Heavy Ion Fusion Virtual National Laboratory (HIF), has nearly completed a series of experiments that test the physics of different parts of such a driver. Multiple intense ion beams have been produced, accelerated, combined, and focused in small-scale experiments whose physics parameters are in the same range as the driver. Present experiments are exploring, in three separate experiments, transport aperture limits, the effect of stray electrons and gas on the beams, beam neutralization, and final focus. When these are completed, much of the basic physics of heavy-ion drivers will have been demonstrated.

The next important step will be to integrate the beam manipulations from source-to-final focus into a single experiment. Since changes to the beam-distribution function accumulate through each phase of the driver, it is important that such an Integrated Beam Experiment (IBX) would be able for the first time to test focusing of a beam that had experienced, in succession, all the processes of a driver. Each part of this experiment would include a rich selection of physics experiments. In the accelerator, longitudinal wave formation and propagation would be studied for the first time for a space-charge-dominated ion beam, along with beam halo formation, the temperature anisotropy instability, electron dynamics and its effect on focusing, and other processes of nonneutral plasma physics that are crucial to beam quality. Following the accelerator, the longitudinal "drift compression" of the beam by a large factor (~10), and the focusing and final neutralization of the beam would be studied. As one of its important goals, the IBX would benchmark present computer codes. Confidence in the ability of these codes to predict the beam dynamics from source to focus would greatly decrease the risk and cost of future experiments.

The Heavy Ion Fusion (HIF) Virtual National Laboratory, consisting of the HIF programs at Berkeley Lab, Lawrence Livermore National Laboratory, and Princeton Plasma Physics Laboratory, is formulating a preconceptual design for the Integrated Beam Experiment, which could be ready for physics validation review by the Fusion Energy Sciences Advisory Committee by early FY 2005.

Heavy-Ion Fusion Integrated Beam Experiment Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	5.3	5.3	5.3	5.3	5.3	26.5
Equipment	0.4	0.4	0.4	0.4	0.4	2.0
IBX Construction	5.8	8.7	14.7	15.5	16.6	61.3

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code AT).

Office of High Energy and Nuclear Physics

Supernova Astrophysics: SuperNova/Acceleration Probe (SNAP)

Recent studies of Type Ia supernovae, including measurements by the Supernova Cosmology Group at Berkeley Lab, produced significant evidence that, over cosmological distances, the supernovae appear dimmer than would be expected if the universe's rate of expansion were constant or slowing down. This was the first direct experimental evidence for an accelerating universe potentially driven by a positive Cosmological Constant. However, only about 80 supernovae accumulated over several years have been studied, and other explanations have not been completely ruled out.

A space mission is now being designed that would increase the discovery rate for such supernovae to about 2,000 per year. Discovery of so many more supernovae would help eliminate possible alternative explanations, give experimental measurements of several other cosmological parameters, and put strong constraints on possible cosmological models. The satellite called SNAP would be a space-based two-meter telescope with a one square degree field-of-view with 500 million pixels. Such a satellite would also complement the results of proposed experiments to improve measurements of the cosmic microwave background.

In addition to the supernova discovery program itself, Berkeley Lab's Supernova Cosmology Group has unique expertise in large charge-coupled device (CCD) detectors. While smaller CCDs are now common, the Laboratory has developed techniques to construct the large mosaics required for SNAP by stitching together several hundred of the largest ones. The group has also devised a way to manufacture the detectors at significantly reduced cost. Technically, the CCDs have high resistivity with excellent quantum efficiency at one micron, which is the same as the emission from distant Type Ia supernova and where conventional CCDs have very low sensitivity.

After several years of research and development, the project schedule calls for approximately four years to construct and launch SNAP, and another three years of mission observations. A detailed budget and schedule will be developed in coordination with DOE's Office of Science and the National Aeronautics and Space Administration (NASA) to advance an interagency collaboration on the project.

Supernova Astrophysics: SuperNova/Acceleration Probe (SNAP)
Resource Requirements ($M)*

	2003	2004	2005	2006	2007	2008	Total**
Operating/Equip.	3.5	8.3	18.1	58.2	123.2	153.8	366.5

*Preliminary estimate of Budget Authority (B&R Code KA) and Work for Others (NASA). Full project cost estimate will be developed as part of CD-1 expected in FY 2005. Funding among partners is under discussion.

**Contingency budgets not included in spending profiles. Total includes prior year operating funding. Total estimate through 2010 is $684.5M.

Accelerators to Probe the Origin of Mass

A fundamental unanswered question in High Energy Physics is that of the origin of mass. In the standard model of particle physics all of the masses arise from interactions of the particle in question with a "Higgs field." The simplest implementation of this Higgs field involves the existence a single new particle, the Higgs boson, whose mass is not predicted by the theory but whose interactions are. In order to understand the mass generation mechanism it is necessary to discover these Higgs bosons and any other associated particles (such as those predicted in models of super symmetry) and to measure their couplings to the other particles of the standard model.

In order to be consistent with experimental measurements, the Higgs mass should lie between the current lower limit of 114 GeV and approximately 200 GeV. In more complicated implementations, there can be more Higgs bosons with masses ranging up to 1 TeV. The Large Hadron Collider (LHC) is designed to have sufficient energy and luminosity (event rates) to discover at least one Higgs boson, independent of the actual implementation. The LHC will search for Higgs bosons via decays into photons, W and Z bosons, τ leptons and b-quarks. The mass will be measured and some of the couplings and decay properties determined. The LHC has a much larger available energy than the Tevatron at Fermilab and this opens up a new energy regime that will allow the LHC to conduct extensive searches for other new phenomena such as super symmetric particles and the existence of extra dimensions. It is also likely that the LHC could produce the particle responsible for the Dark Matter that permeates the universe according to astrophysical observations.

While the LHC will discover the Higgs boson and provide data of enormous significance in improving our understanding of the fundamental properties of matter, it is not expected to be able to observe all of the decays of Higgs bosons and measure all of the couplings precisely. For this, additional experiments will be required. Some of these could be accomplished by upgrading the LHC in either luminosity or energy. If an electron positron collider of sufficient energy and luminosity could be constructed, it could complete the picture by measuring precisely the properties of the Higgs bosons and other new particles. In this respect the LC would do for the Higgs boson what the LEP collider at CERN did for the Z. While the Z was discovered and many of its properties measured in proton collisions, the precise measurements of its properties at LEP provided the ultimate confirmation of the properties as predicted by the standard model.

Berkeley Lab has core competencies in many areas needed to design and construct the next generation of accelerators for high energy physics, including expertise in accelerator simulations and theory, radiofrequency (rf) hardware and diagnostic devices, superconducting magnets, and induction linacs. A state-of-the-art laser-plasma acceleration facility is also exploring the possibility of very high gradient acceleration.

With respect to the LHC, the laboratory is part of the U.S. LHC Accelerator Project, a national collaboration that works on critical accelerator physics issues, and that will deliver accelerator hardware to CERN. Laboratory staff are also taking leadership roles in the new initiative towards supporting accelerator research at the LHC and the LHC Accelerator Research Program (LARP). The work of the proposed LARP is essential to maximizing the return on investment in the LHC by enabling the collider to reach its design luminosity at the earliest possible time. The proposed Berkeley Lab efforts in building bunch -by-bunch luminosity and beam density monitors are especially critical in this regard. The LHC will present the best opportunity for training accelerator physicists in the challenges of operating a collider at very high luminosity. Consequently, the third component of LARP will involve the substantial presence of accelerator physicists from partner laboratories at CERN through machine commissioning and early operations. In the longer term, work of high-field superconducting magnets with Nb_3Sn will be critical for increased luminosity and for increased energy. The practicality and potential of such magnets has been demonstrated by the Superconducting Magnet Group at Berkeley Lab. These upgrades will significantly enhance the physics reach of the LHC.

Preliminary design approaches for a Linear Collider are being developed in collaboration with Stanford Linear Accelerator Center, Fermi National Laboratory, Brookhaven National Laboratory, and Lawrence Livermore National Laboratory, and internationally with the Japanese Center for High Energy Physics (KEK). The goal is an accelerator colliding positrons and electrons at a 500 GeV to 1.5 TeV center of mass collision energy. Berkeley Lab is actively working on the accelerator physics associated with this system of accelerators, with particular attention to the damping storage rings necessary to achieve high luminosity and small emittance. This property is essential to achieve the extremely large collision rates (luminosity) needed for physics studies. Our work on the damping rings includes lattice design and layout, instabilities and their suppression, and engineering designs for the radiofrequency (rf) power systems and components, magnets, damping wiggler, and vacuum systems.

While this is underway, Berkeley Lab will also be involved, as part of a multi-laboratory collaboration, in detector development. Design studies have begun, aimed at understanding the detector performance needed for precision measurements in the presence of intense machine backgrounds, as well as at elucidating the detector research and development effort needed to support the conceptual and engineering design of a prototype detector.

Accelerators to Probe the Origin of Mass
Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating**	1.7	3.3	4.1	4.9	5.0	19.0
Equipment	0.5	2.1	2.7	5.5	12.6	23.4

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KA).
**Resource projections are for planning activities, eventual funding subject to DOE decisions on CD-0 and CD-1 for the respective accelerators.

The Future of Neutrino Physics

The study of neutrino properties is undergoing a renaissance. From recent measurements at Sudbury Neutrino Observatory (SNO) and KamLAND, we have discovered that neutrinos can change their flavor and, therefore, have mass—and in the process have taken the first steps beyond the Standard Model of particle physics. We have learned that the explanation of these puzzles is neutrino oscillations. This new understanding of neutrino properties has established a new field of inquiry. We now envision an experimental program extending over decades that will establish whether neutrinos are their own antiparticles, determine an absolute mass scale, measure masses and mixing parameters with increasing precision, search for charge parity (CP) violation in neutrino oscillations, and detect neutrinos coming from the cosmological birthplaces of ultra-high-energy cosmic rays.

The most important open question is also the most fundamental, namely: are neutrinos their own antiparticles? In order to extend the Standard Model to include neutrino mass, we must answer this question. We must also determine the absolute mass scale of neutrinos. Although tremendous progress has been made on the measurement of neutrino mixing angles, further measurements are needed to determine whether it will be possible to search for CP violation in the neutrino sector. Precise values of the mass differences and associated mixing angles will be required for tests of models going beyond the Standard Model. Answering these questions will require neutrinoless double beta decay experiments (for neutrino type and absolute mass scale) and neutrinos from the Sun, reactors, and accelerators (for mass and mixing angles, mass hierarchy, and CP violation).

At Berkeley Lab, the SNO and KamLAND experiments, after reporting initial results, are in their most productive phases. We will have values from SNO for the neutral current and charged current reaction rates for ^{8}B solar neutrinos. The energy spectrum of antineutrinos at KamLAND will result in tighter constraints on mixing. Cuoricino, a prototype for the next generation of double beta decay experiments, has just begun taking data at the Gran Sasso underground laboratory in Italy. In the long run, accelerator neutrino beams will be needed for measurements of CP violation and will be used to determine the mass hierarchy. Muon cooling is needed for a muon-storage-ring-neutrino-factory, and thus a neutrino factory is a first step towards a muon collider. Berkeley Lab is deeply involved in the international R&D effort toward a future neutrino factory through its role in MICE, the Muon Ionization Cooling Experiment. For the past three years Berkeley Lab has been designated by DOE to be the site of the Project Office for managing the research and development work of the Neutrino Factory and Muon Collider Collaboration.

The future program at Berkeley Lab is likely to have the following components: neutrinoless double beta decay, a reactor measurement of mixing angles and tests of the Standard Solar Model, accelerator physics directed towards a neutrino source, and support of NUSEL, the National Underground Science and Engineering Laboratory. NUSEL may actually be realized in the near future if the NSF decides to proceed with the development of the Homestake Mine in South Dakota (or some other site). NUSEL will permit the development of next-generation experiments in neutrino physics and double beta decay, with its significantly decreased backgrounds and with an exceptional advantage of being a dedicated facility. Geoscientific investigations will also be part of the program at NUSEL, and the Earth Sciences Division (ESD) at Berkeley Lab has participated in this national initiative from its inception. NUSEL offers excellent interdivisional research opportunities.

The Future of Neutrino Physics Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating**	1.3	2.3	0.3	0.3	5.3	9.5
Equipment	1.8	2.4	7.7	8.2	0.2	20.3

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KA).
**Resource projections are for planning activities, eventual funding subject to DOE decisions on CD-0 and CD-1 for the respective accelerators.

Gretina to GRETA (Gamma-Ray Energy Tracking Array)

For many years, Berkeley Lab has been one of the leaders in the development of gamma-ray detector arrays with high-energy resolution, high efficiency, and good peak-to-background ratios. This type of array is an important tool for the study of nuclear properties and is expected to be especially important for advanced nuclear structure studies in the Rare Isotope Accelerator (RIA) era. Researchers at Berkeley Lab conceived the idea and carried out the construction of Gammasphere, currently the most powerful array of its type in the world. From April 1993 to September 1997, this national facility was in use at the 88-Inch Cyclotron, and over 200 experiments were carried out with about 300 participating users. After operating at Argonne National Laboratory from late 1997 to early 2000, Gammasphere came back to the 88-Inch Cyclotron to continue its forefront research program and service to a broad spectrum of nuclear scientists from universities and institutions around the world. Gammasphere completed its second campaign at the 88-Inch Cyclotron in late 2002 and is now operating again at Argonne National Laboratory. Communities in both the United States and Europe are working on the next generation of detector arrays to open up new scientific opportunities.

A new concept for a gamma-ray energy-tracking detector is being developed by the Berkeley Lab nuclear Structure Group, in association with others in the community. This detector is a shell consisting of closely packed, highly segmented germanium detectors. By determining the energy and the position of each interaction point, the original gamma rays can be reconstructed by tracking algorithms, and thus the name of the array. It represents an advance in detector development that may well be comparable to that seen when germanium detectors were first introduced. The full 4π GRETA array (comprising ~100 segmented germanium crystals) could reach a total efficiency of approximately 60 percent, which will give it a resolving power 1,000 times larger than that of current arrays. The 2002 Nuclear Science Advisory Committee Long Range Plan has endorsed the merit of the proposed GRETA.

Research and development efforts have demonstrated the proof-of-principle and initial funding has been received to construct a prototype GRETA module consisting of three highly segmented coaxial germanium crystals in a common cryostat. This module represents a first-generation energy tracking detector and is an essential next step towards a full 4π tracking array. This three-crystal prototype will be delivered in FY 2003 and will be used in a number of experiments for full characterization, and to confirm the design and simulation calculations, in particular for tracking across crystals.

Working with the GRETA steering committee and the various working groups, the next step on the way to the full GRETA detector is to design and build Gretina (1/4 of GRETA)—a nine-module (27 crystal) array. The estimated funding profile for the construction of Gretina is given below. This nine-element array will define the packaging scheme of GRETA, establish the reliability of mounting multiple crystals in a single cryostat, and provide benchmarks for electronics and data acquisition systems. More importantly, an exciting physics program has been identified for Gretina.

A comprehensive series of measurements (primarily carried out on a 36-segment single-crystal GRETA prototype) and simulations has demonstrated that it is possible to build a gamma-ray tracking detector today. The proof-of-principle was achieved in four key areas: (1) the manufacture of both segmented detectors and pre-amplifiers that can provide the high-quality signals needed to resolve and locate individual interaction points, (2) the use of signal processing methods to determine the position, energy, and time of gamma-ray interactions based on pulse shape digitization and digital signal processing, (3) the development of a tracking algorithm that uses the energy and position information to identify interaction points belonging to a particular gamma ray, and (4) the design and packing schemes for the module, Gretina, and the full 4π GRETA array.

To be in a position to exploit the science opportunities in a timely manner we must move forward with construction. With the requested funding profile, Gretina could start its physics program in FY 2007. It will be used in ongoing experiments at stable beam, fragmentation, and ISOL facilities. Assuming its success, we would then expect to continue with the construction of the full GRETA array (TEC ~$60M). Such a 4π device is seen as an essential detector for nuclear structure studies at RIA.

Gretina Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	0.6	0.4	0.0	0.0	0.0	1.0
Equipment	1.0	2.5	3.0	3.9	4.4	14.8**

*Preliminary cost estimate of Berkeley Lab Budget Authority (B&R Code KB).
**Total TEC for Gretina as major item of equipment (MIE) is $17.0 M through FY 2010.

New Windows on the Microwave Universe

DOE has long been a pioneer and leader in observations and theory of the Cosmic Microwave Background (CMB) Radiation. At Berkeley Lab we began making observations and developing CMB theory in the early 1970s and we were leaders in the COBE mission. We participated in both the BOOMERanG and MAXIMA experiments, and data for both experiments were analyzed at Berkeley using the facilities and expertise at NERSC. We are currently participating in a number of experiments including MAXIPOL and PLANCK. We are also collaborating in three next-generation experiments to substantially improve constraints on fundamental cosmological constants and to probe the inflationary era, APEX-SZ, the South Pole Telescope (SPT), and POLARBEAR.

APEX-SZ and the South Pole Telescope will utilize the Sunyaev-Zel'dovich (SZ) effect to search for distant galaxy clusters. The distribution of galaxy clusters vs. redshift is sensitively dependent on the mass density, energy density, and equation of state of the universe. Unlike x-ray or optical surveys, the magnitude of the SZ signal is independent of redshift, so it is well-suited for deep searches. These experiments are complementary to SNAP as they attack the same physics with a completely different technique. The third experiment, POLARBEAR, aims at detecting gravity waves generated by inflation. This measurement was the first recommendation of the National Academy of Sciences Panel chaired by Michael Turner. The gravity waves could manifest themselves as a net curl in the polarization field of the CMB.

APEX-SZ will commence in early 2004, and the South Pole Telescope is scheduled for first light in 2006. The effort for these experiments is currently centered on the UC Berkeley campus and funded primarily by NSF, but Berkeley Lab is making key contributions. We are now building prototype detectors for POLARBEAR at the Laboratory.

These experiments rely critically on new developments in detector technology. Sensors for millimeter-wavelengths are already limited by the photon shot-noise of the CMB signal, so the only way to improve the sensitivity to the level required by these next-generation experiments is to perform more measurements simultaneously and to extend the observing time. Since the current set of experiments can be ground-based, rather then balloon-borne such as BOOMERanG and MAXIMA, the measurement time can be extended readily. However, this is not sufficient to gain the 10^5 increase in sensitivity required to map the predicted gravitational signal. Thus, the array size must be increased beyond the 10 to 20 sensor arrays of previous experiments to thousands of pixels.

This has been made possible by technology developments in Berkeley that allow the wafer-scale integration of sensor arrays using the techniques of silicon microelectronics and micromachining. Fabrication of 1000 sensors on a 100 millimeter wafer has been demonstrated. The sensors typically operate at about 0.5 degrees Kelvin, so the heat leak due to many connecting wires is prohibitive. Furthermore, an economical readout technique is crucial. We are developing multiplexing techniques that incur no additional power dissipation on the sensor stage. Berkeley Lab has been key in designing the superconducting multiplexer and developing the readout. An important ingredient is our experience in large-scale readout systems for high energy physics, coupled with the software needed to control and monitor a large experiment. We are also planning a new Superconducting Sensor Array Laboratory to allow reliable fabrication of the sensor arrays with high yields.

Crucial to the success of this scientific program is tight coupling with theory and computational science. Collaboration with NERSC Center provides crucial computational expertise and computing cycles. We have seen how the interplay between forefront efforts in high energy physics and cosmology has opened the window to new physics. The synergy between universities and national labs, and between particle physics and cosmology, will be crucial in probing this new physics frontier.

New Windows on the Microwave Universe Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	0.3	0.3	0.3	0.3	0.3	1.5
Equipment	0.5	0.8	0.8	1.0	2.0	5.1

* Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KA, KB and WFO).

Workforce Development of Teachers and Scientists

Workforce Development of Teachers and Scientists

A secure future for our nation requires a strong science and technology capability. The number of American students choosing to pursue science, engineering, computing sciences, and technology careers is not keeping pace with the need. The demographics of science and engineering students in our colleges and universities does not represent the diversity of our population. At the precollege level many students are not receiving a quality mathematics and science education that promotes science literacy and ensures access to scientific and technological careers. Many of these students are being taught by teachers lacking adequate academic preparation in science and mathematics. The Department of Energy educates future scientists and engineers through mentored research and training experiences at its national laboratories. Berkeley Lab will increase the number of students and teachers receiving education and training at our Laboratory. Partnerships will be developed with faculty at colleges and universities serving large populations of underrepresented minorities, and with local and regional community colleges and school districts.

Berkeley Lab, through its Center for Science and Engineering Education (CSEE) will:

- Increase the number of U.S. students who become scientists and engineers through education and training of students preparing for postgraduate studies.
- Promote access to scientific and technical careers for all students, including women, minorities, the handicapped, and the economically disadvantaged.
- Increase the number and strengthen the preparation of precollege mathematics and science teachers.
- Support increased classroom emphasis on, and knowledge of, frontier science and technology and the methods of scientific inquiry.
- Promote scientific literacy and public understanding of science and technology.

Berkeley Lab will increase the number of undergraduate science, engineering, and technology students and precollege science, mathematics, and technology teachers participating in mentored research and training experiences. Support will be provided for faculty/student teams to collaborate in research projects at Berkeley Lab. The Office of Science has established a successful online national recruitment and selection process. The Center for Science and Engineering Education establishes partnerships with faculty at minority-serving institutions, with universities preparing future teachers, with science and technology centers, and with local and regional school districts. These strategic partnerships ensure that education and training opportunities at Berkeley Lab meet the needs of the participants, promote follow-through and tracking of participants, and strengthen the quality of education at the partner institutions.

Berkeley Lab's Center for Science and Engineering Education identifies and supports student and teacher mentors and facilitates participation in education outreach by staff at Berkeley Lab. Training, communication, evaluation, and recognition of staff participating in these activities are key components that will be enhanced to support the proposed increased opportunities for students and faculty, and a strong education component in public affairs.

Workforce Development of Teachers and Scientists
Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	2.5	3.0	3.0	3.0	3.0	14.5

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code KX and WFO).

OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

Solid State Lighting—Next-Generation Lighting Products

Lighting uses 765 terawatt-hours (TWh) of primary energy, or 22 percent of the total electricity generated in the U.S. Nearly 80 percent of this energy is used within residential and commercial buildings. Thus, the development of new general illumination products having improved efficiency will significantly reduce total U.S. electrical energy use and, consequently provide associated environmental and energy security benefits.

The potential of solid state lighting to significantly reduce the energy used for lighting in commercial and residential spaces has been identified by DOE as one of the greatest near-term opportunities in the development of new energy efficient technologies. Solid state lighting devices such as light emitting diodes (LEDs) and organic light emitting diodes (OLEDs) are emerging technologies that have the potential to be a dominant general lighting source for the future. Currently available white LEDs have an efficacy of 30 lumens/watt, significantly higher than both standard incandescent and halogen light sources. However, major improvements in device performance are needed for both LEDs and OLEDs before these devices will match and then go on to exceed the high performance of the fluorescent and the high intensity discharge lamps. Because of the flexibility of solid state lighting (both in uses and different applications) a high efficacy, competitive prices, and a multiplicity of innovative uses suggest a very dynamic entry of the products into the marketplace as they become commercially viable.

Berkeley Lab intends to carry out the overall research activity as part of a strategic partnership with Sandia National Laboratories. This is an excellent opportunity for the basic and applied researchers in this field in Berkeley Lab, university campuses, and Sandia to collaborate to achieve new lighting products. This collaboration will also be coupled with private industry.

The proposed Berkeley Lab research on LEDs will focus on improving the performance of the total device through improvements in the performance of each component and overall system design. Research will continue on: 1) understanding fundamental processes that improve the conversion efficiency of electric power to light within the die; 2) enhancing the conversion of the LED light to white light with improved materials; 3) improving the extraction efficiency of light from the die through optical modeling and research on phosphors, and coating technologies; and 4) developing high luminous sources through the efficient aggregation of multiple LEDs, using improvements in packaging that incorporate enhanced optics and thermal management techniques.

The proposed Berkeley Lab research in OLEDs will focus on improving the performance of the OLED light source in a manner parallel to the approach used for LEDs. Incremental improvements will be realized through research on: 1) the development of more efficient organic emitters through an understanding of competing nonradiative processes, 2) development of materials to improve electron injection through fundamental understanding of the electronic processes, 3) developing analytic tools to study and better understand degradation processes of OLEDs, and 4) improving the extraction efficiency of the device by designing and building better encapsulating techniques appropriate for lighting application devices. The research program will be highly multidisciplinary and multi-institutional, working across Berkeley Lab divisions and involving university and industry collaborators.

Solid State Lighting Resource Requirement ($M)*

	2004	2005	2006	2007	2008	Total
Construction	2.5	4.0	5.0	5.0	5.0	21.5

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code EE).

OFFICE OF FOSSIL ENERGY

Geologic Carbon Sequestration

One of the proposed strategies to reduce the build-up of greenhouse gases in the atmosphere is to capture carbon dioxide from large point sources, such as fossil-fueled power plants, and sequester it in the deep underground. Geologic formations such as oil fields, coal beds, and aquifers are likely to provide the first large-scale sinks.

Study of geologic sequestration of carbon dioxide is carried out on behalf of DOE's Fossil Energy Program in the Berkeley Lab-led GEO-SEQ Project. This is a joint study with Lawrence Livermore and Oak Ridge National Laboratories, along with twelve industrial and academic partners, to investigate the feasibility and collateral benefits, for the long-term storage of carbon dioxide in depleted oil and gas reservoirs, brine formations, and coal beds. The current program is to conduct and manage a set of targeted, interrelated, applied research and development tasks that will:

- Lower the cost of sequestration by developing optimization methods for sequestration technologies with collateral economic benefits.
- Lower the cost of sequestration by optimizing trade-offs among the costs of carbon dioxide separation, compression, transportation, and geologic sequestration alternatives.
- Help developers to select sequestration sites by providing reliable information about the location and capacity of suitable geologic formations.
- Increase the effectiveness and safety of geologic sequestration by demonstrating cost-effective and innovative monitoring technologies.
- Enhance methods to predict and verify that long-term sequestration is safe and effective.
- Identify and pursue early opportunities to apply these technologies in pilot tests to facilitate near-term market penetration and commercial application.

Experience developed in the GEO-SEQ Project ideally positions Berkeley Lab to lead the development of a Regional Carbon Sequestration (RCS) Center in California. The California RCS Center would be one of perhaps five such centers established to address the challenges posed by the diversity of carbon dioxide sources, geologic sinks, and technology options present throughout the United States. The California RCS Center will provide California-specific scientific data, technology development, and public outreach needed to ensure environmentally safe, technologically sound, and publicly acceptable options for geologic sequestration of carbon dioxide. This broad scope requires a partnership between national laboratories, academia, energy producers and users, and state and local agencies. The Center will conduct and manage studies to support performance assessment, monitoring, and capacity assessment of sequestration sites in California, leading, ultimately, to verification and validation of sequestration approaches in large-scale demonstrations. The Center will work with its industrial partners to develop commercially viable sequestration technologies, with field demonstrations once again providing proof of concept. Development of sequestration-based enhanced oil and gas recovery will be early focuses. The Center will work with state and federal regulatory agencies, providing input on health and safety risk and other factors needed to establish a regulatory framework for geologic sequestration. Finally, the Center will work with state and local agencies to inform and educate the public about geologic sequestration.

Geological Carbon Sequestration Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	1.0	3.0	6.0	8.0	10.0	28.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code AA).

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

New Science at Yucca Mountain

In February 2002, the President of the United States notified Congress that he considers Yucca Mountain to be qualified for a construction permit application, taking the next in a series of steps required for approving the site as a nuclear materials repository. This milestone marked the conclusion of the site characterization phase for the Yucca Mountain Project and, pending congressional approval, will usher in a new phase, that of preparation for License Application to the Nuclear Regulatory Commission in year 2004. Work leading to License Application will be performed in a schedule-driven, compliance framework. The DOE Office of Civilian Radioactive Waste Management is concurrently developing a new Science Initiative to promote pursuits of important scientific investigation of the Yucca Mountain site in an environment supportive of scientific research. This science program is intended to be a parallel effort to the fast tract licensing activities.

The stated purpose of this science initiative is a plan for enhancing confidence, technology, and efficiency in the repository program and the larger waste management program. Criteria for identifying and selecting investigations for the Science Initiative include reducing uncertainty as it relates to performance of the natural and engineered systems in the regulatory time and post regulatory time frames, cost and time savings to the repository program, and results to be available in the 2004 to 2010 time frame. The Science Initiative will be opened to both the national laboratories and universities. Berkeley Lab is well positioned to contribute to this Science Initiative.

Berkeley Lab has played a key role in the site characterization phase of the Yucca Mountain Projects. Our work has focused on *in-situ* hydrological and thermal testing, and the development of comprehensive numerical models of flow and transport in the unsaturated zones. Results of our investigations have greatly advanced the knowledge of flow and transport in thick, fractured, unsaturated rocks, and have contributed to the successful recommendation of the Yucca Mountain site by the President. Scientific issues still remain and need to be addressed to enhance confidence and reduce uncertainty in the ability of the natural system to isolate radioactive waste. The remaining issues include:

- Flow focusing and discrete flow paths in the mountain.
- Impact of coupled processes (thermal, hydrological, chemical, mechanical) on flow and transport.

- Function of the zone of reduced water saturation and flow beneath the waste emplacement drifts to favor diffusive release of radionuclides into the rock matrix, and to substantially reduce the rate of radionuclide transport.

These topics are excellent candidate areas for Berkeley Lab's contribution to the DOE Science Initiative.

New Science at Yucca Mountain Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	3.0	3.5	4.0	5.0	6.0	21.5

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code: Nuclear Waste/Other DOE Contractor).

OFFICE OF ENVIRONMENTAL MANAGEMENT (EM)

Development of Site-Specific Conceptual Models

Berkeley Lab has been organizing an initiative that will utilize the Laboratory's modeling and biogeochemistry expertise to assist the DOE Office of Environmental Management with closure activities, especially at smaller sites. The Laboratory will lead a group of scientists and engineers from across the DOE complex to focus on developing conceptual model for geohydrology, especially as it relates to contaminant fate and transport and environmental risk. These conceptual models will be linked to the most appropriate numerical models to provide a dynamic and robust tool for site managers and long-term stewards to best manage and communicate subsurface contamination risk to the public, regulators and restoration vendors. Since DOE intends to close more than 75 of its 120 sites by 2010, there is a critical need for strong subsurface conceptual models for each site. DOE Office of Science and Technology within EM is very interested in testing this approach, and is currently making arrangements with Berkeley Lab to do a pilot test at the Mound Site in Ohio.

Development of Site-Specific Conceptual Models
Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	1.5	2.5	3.5	4.0	4.5	16.0

* Preliminary estimate of Berkeley Lab Budget Authority (B&R Code EX).

Closing Water and Chemistry Budgets in Critical Supply Basins

A perplexing problem in addressing water availability and water quality is understanding hydrogeochemistry of water basins. Central to this understanding is balancing the atmospheric moisture budget and the surface and subsurface water budget. This "closing" the water budget over regions of the world is an important objective of earth science research. However, little information is available on how climate changes and climate variability might affect groundwater aquifers, including quality, recharge rates, and flow dynamics. New research on these issues is needed in order to make progress on this challenging and important area.

The water and chemistry budget closure within river basins is a problem that continues to elude hydrologists and climatologists. Closure requires new methodologies for fully characterizing such open water systems and testing numerical simulations over time to understand storage, transfer rates, flow paths, and chemistry/contaminant transport and concentration, as a function of variability due to climate, land-use change, and other phenomena.

The San Joaquin Basin represents the river-basin test bed for closure studies, as it is a region of major importance to California's agricultural and industrial economy. New scientific approaches that couple regional top-of-the-atmosphere to deep groundwater modeling and validation will be in the forefront of hydroclimate research. This fundamental science achievement will be applied to the development of state-of-the-art San Joaquin models on water allocation and conjunctive use that will be used to improve upon existing State of California and U.S. Bureau of Reclamation models. Additionally, a critical application of the work will be in developing a full understanding to optimally address the long-term impact of DOE remediation activities at sites that reside in large river basins. Taking the total water supply balance into account at such sites as Hanford (Columbia River basin) and Savannah River will result in critical decisions on the use of natural attenuation versus active cleanup.

Closing Water and Chemistry Budgets
Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	1.0	1.5	2.5	3.5	4.0	12.5

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code EX).

DEPARTMENT OF HOMELAND SECURITY

Reducing Chemical and Biological Threats in Buildings

In the event of a terrorist release of a chemical or biological agent, the majority of the population will be within buildings. Potentially, many lives can be saved, and mitigation costs can be reduced, through appropriate building design and operation. Current research uses computer models and experiments to address a variety of questions related to optimum building operation: how much time is available for action or evacuation, where should "shelter-in-place" rooms be located, what fraction of biological particles will deposit on ventilation filters or in ducts, where should sensors be placed. Unfortunately, several critical aspects of agent behavior indoors are poorly understood, which makes exposure and response prediction difficult and highly uncertain. Important unknowns include commercial building air infiltration rates, and the behavior of airflow in commercial buildings when ventilation systems are shut down. Additionally, much of the current modeling of contaminant transport and behavior assumes nonreactive inert gases, and is based upon empirical data collected from field studies using inert gas tracers. Inert gas models do not include secondary indoor source terms, such as tracking and resuspension of deposited particles, or desorption and re-emission of sorbed gas-phase compounds.

To address all of the problems mentioned above, an ambitious research program is proposed with the following elements:

- Develop a second-generation integrated building transport model. This model would address processes such as building airflow and contaminant transport; chemical-agent sorption and desorption; size resolved particle deposition, infiltration, filtration, resuspension, and tracking;

incomplete mixing in large interior spaces; stack effects and vertical transport; contaminant removal systems; and emergency response modes.

- Determine experimentally the values of important physical parameters that control particle deposition, tracking, re-suspension, and gaseous reactivity. Currently, some phenomena such as particle re-suspension and tracking (of crucial importance in the anthrax attacks of 2001) are poorly understood. This work will also develop models of exposures to these agents that account for agent deposition and resuspension, and for the activities of people.
- Determine building-related parameter values by performing observational and intervention experiments in existing buildings; these experiments will also quantify model accuracy. These experiments will use a new generation of highly time resolved tracer measurement devices that can be deployed unobtrusively in an occupied high-rise building to obtain data with a dense spatial and temporal resolution. The experimental data will improve the fidelity of the integrated building transport model and reduce the uncertainty in model predictions.

The improved prediction of airborne concentrations in commercial buildings will substantially improve our ability to plan for, predict the effects of, and mitigate potential chemical or biological attacks. The behavior of naturally occurring chemicals and biological aerosols will also be predicted by the models, so this research will find application to general problems concerning exposures to pollutants that cause or exacerbate asthma, allergies, irritation, and communicable respiratory illnesses.

Reducing Chemical and Biological Threats in Buildings
Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	2.0	2.5	3.0	3.0	3.0	13.5

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code Homeland Security).

WORK FOR OTHERS

Advanced Controls for Energy Efficiency and Distributed Energy Systems

Over 65% of electricity use in the United States is in buildings. About half of that total is in commercial buildings. As a result of building research, improvements have been made in the energy efficiency of many of the specific technologies in commercial buildings: lighting, heating, air conditioning, and ventilation systems, as well as the shell of the building (windows and walls). A typical office building constructed today uses considerably less energy than one built one or two decades ago.

However, there are very large and cost-effective energy improvements possible that go well beyond today's levels. The key to achieving many of these improvements is to create a new generation of intelligent control systems. Traditional efficiency concepts like improved insulation were static—once installed their performance was assured. Newer systems such as electrochromic windows that darken or lighten with a control voltage, or photosensor-controlled, dimmable lighting require more sophisticated sensing and control technologies for proper operation. In this evolving concept of a smart building with advanced controls, the interaction among building elements is critical, as is the interaction of the building with its occupants, with weather patterns, and with dynamic utility pricing.

The Berkeley Lab vision of a smart building begins with a commissioning phase after construction to ensure that the building is delivered to the owner with all of its hardware and software systems working as intended. Performance changes as elements age or building use changes. Berkeley Lab's continuous commissioning concept would apply an extensive sensor and communications network to compare performance to expectations, identify problems, and diagnose and correct as many as possible without direct human intervention. Some of this is work is done today with measured savings but the cost is high as skilled personnel are required for the management, diagnosis and intervention. Smarter building systems could capture and simulate the behavior of skilled practitioners continuously and automatically. For this to happen, and be affordable, low-cost control systems with very inexpensive sensors, controls, and robust software are needed.

One possibility to create such smart systems is to combine the control system design at Berkeley Lab with a new generation of wireless communication systems being created at UC Berkeley, and to introduce a new generation of low cost sensing and actuating chips in energy-using equipment that can serve as control points. Ultimately every light fixture, window, ventilation damper, and power consuming element in a building will be networked in a building-level control system. Together with highly efficient hardware, this approach is an essential enabling technology needed to achieve the 70 to 80 percent load reductions that DOE seeks to achieve their "Zero Energy Building" agency goals by 2020. Smart controls not only provide high levels of energy efficiency and cost savings but also provide electric demand response at times of insufficient supply, and the capability of effective response to natural and man-made disasters. Smart controls not only allow the internal systems in the building to function optimally but allow the building as a while to be a responsive element within the local and regional electric grid.

When energy sources can be located within or near commercial buildings, significant efficiencies can be gained and supply can be matched with end-use devices. Examples of distributed energy systems sized for commercial buildings (or small groups of such buildings) include microturbines used alone or as cogeneration systems, fuel cells, and (perhaps in larger application within a decade) photovoltaic arrays. A "microgrid" can improve local efficiency and reliability as well as provide value to the larger electricity grid. The microgrid consists of: (1) end-use equipment (including electricity- and heat-using devices), (2) distributed power systems (e.g., fuel cells, microturbines, cogenerators, photovoltaic arrays), (3) electricity storage devices (e.g., batteries, flywheels, capacitors) and (4) a hierarchy and variety of information, communication, power electronics, and control systems. The microgrid can receive power from the grid or supply power to it.

The major issues involve the ability of control systems to enable the microgrid to serve as more valuable than the sum of its parts. We anticipate that hierarchical control, in which the overall microgrid is controlled by a supervisory control system, and different types of control will operate for the distributed generation, end-use equipment, and storage. We anticipate creating small-scale demonstrations of microgrids to study their technical characteristics and understand the roles of associated control systems. Other aspects of interest include how the microgrid can be used to maintain stability of the local system under a variety of conditions and to analyze the critical issues in linking with the local distribution grid. We also anticipate modeling of the microgrid, and particularly the set of systems that is needed to provide it with dynamic control. The result of this assessment will indicate the technical challenges that need to be overcome to make the microgrid a widespread commercial enterprise and the conditions under which the microgrid is most likely to be viable. We plan to perform this work in close collaboration with private firms, as well as other research centers, especially members of the Consortium of Electricity Reliability Technology Solutions, a Berkeley Lab-led consortium of four national labs, leading universities, and private firms.

Advanced Controls for Energy Efficiency and Distributed Energy Systems Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	4.0	5.0	5.0	5.0	5.0	24.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Source EE and CEC).

Systems Biology for Understanding Cancer

The genomes of human cancers are remarkable in their complexity and variation between individuals. Most likely, the set of aberrant genes in an individual tumor is the result of an evolutionary interplay between the individual allelic composition, stochastic interactions with environmental clastogens, and chance events during DNA repair so that each is a unique disease. There are, however, genetic, biological, and clinical commonalities in subsets of cancers that suggest the existence of underlying principles of aberration formation and function that, when uncovered, will reveal much about how cancers arise and evolve. This information, in turn, will enhance our ability to detect, prevent, and/or treat these diverse diseases. Numerous genes already have been identified that are important in cancer genesis and evolution. However, analyses of recurrent aberrations suggest that we still know only a small fraction. More importantly, we understand little about how the aberrations form, and we know even less about how collections of aberrant genes interact to produce specific cancer phenotypes. Understanding these processes is a problem in evolutionary systems biology that is worthy of National Laboratory attention.

Berkeley Lab is well poised to make substantial contributions to the understanding of the formation and evolution of cancer—especially breast cancer—by building on several areas of strength. These include:

- Cell biological models of breast cancer developed by Berkeley Lab biologists that reflect the genomic diversity of human cancers, and that enable quantitative assessment of gene function, cell-cell interactions, and molecular evolution.
- Comprehensive molecular analysis technologies, many from the Joint Genome Institute, that provide detailed information about cancer genomes, transcriptomes.
- Ongoing, major investigations into mechanisms of DNA repair and aging that provide insights into processes that fail during aging and/or as a result of environmental influence that allow cancer to develop.
- Advanced microscopies and molecular manipulation technologies that allow the efficient manipulations of biological systems needed to identify quantitative relationships between molecular events and cellular characteristics.
- Bioinformatic expertise to integrate information from diverse sources, and to model the behavior of complex, interacting systems.

These studies will be guided by detailed molecular analyses of primary human tumors generated in a newly strengthened collaboration with the UC San Francisco Cancer Center's Breast Oncology Program.

These studies will provide insights into four fundamental questions: (1) What mechanisms fail as a result of environmental exposure or natural aging that allow tumor development, and how can effective measures be developed to counter these failures, thereby preventing cancer formation? (2) What are the genetic and biological characteristics that differ between normal and tumor cells, and how can these differences be exploited to improve cancer detection and therapy? (3) How do the aberrant genes in cancers interact to influence phenotypes, such as unchecked cell proliferation; reduced apoptosis; altered interactions with extracellular matrix, growth factors and hormones; increased genome stability;

angiogenesis; and invasion and metastasis? And (4) how does the individual genotype influence susceptibility to cancer, and how can this information be used to predict cancer susceptibility?

Systems Biology for Understanding Cancer
Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	1.0	4.0	5.0	5.0	6.0	21.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code WFO:NIH).

Cell Design Institute

Genetic engineering will benefit immensely from the vast amounts of accumulating biological data, eventually enabling us to engineer entirely new organisms with the ability to convert plentiful, renewable resources into energy, to synthesize complex chemicals inside the cell to replace environmentally unfriendly chemical syntheses, to rapidly synthesize drug candidates to fight human ailments, to produce novel biomaterials for drug delivery and tissue regeneration, to seek out and destroy human pathogens, and to remediate recalcitrant environmental contaminants. Until now, genetic engineering has focused largely on isolated pathways or regulatory circuits without considering the organism as a whole. Not surprisingly, the genetic redirection often falls short in meeting its full potential when the manipulated pathway is considered *in vacuo*. Engineering such organisms cannot be achieved via single-gene or single-pathway engineering alone.

We propose the development of an institute dedicated to designing microorganisms to solve a host of problems that humans face, problems for which there are currently no solutions or for which the solutions are uneconomical, environmentally unfriendly, or unhealthy to humans. The institute will capitalize on the recently sequenced microbial genomes, the availability of tools to examine and manipulate the molecules of life, the extensive biological literature and databases, advances in computing power, and the extensive human capital present at the University of California at Berkeley and San Francisco (through QB3), the Joint Genome Institute, and the Berkeley Lab. Besides doing cutting-edge research, the institute will train students in all the technologies necessary for engineering microorganisms, provide a central place for scientists to aggregate to exchange ideas and develop technology to aid in this area, establish a common infrastructure for engineering, including automation and screening technologies that scientists engaged in these areas commonly need, and create an organizing framework for large projects directed to particular applications and technology development.

In the short term, we will retool existing microorganisms to solve those problems for which a new organism is not necessary, and develop tools and facilities that will enable design and construction of entirely new microorganisms. Not only will these tools be useful for creating entirely new microorganisms, they will also be useful to biologists and engineers to study and manipulate existing microorganisms. Examples of tools include 384-well plate chemostats and libraries of genes for metabolic pathways and microbial parts that can be assembled into a functioning whole. Facilities include an automated microbial core facility and a high throughput functional genomics core. In the long term, we will design and build microorganisms *de novo*, a strategy that will afford better control of biological processes, better conversion rates for the products of interest, and more economical processes.

Because of the value of these “designer microbes” and the tools that enable their design, we anticipate that this institute will play important roles in national security, energy self-sufficiency, and the California and national economies.

Cell Design Institute Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating/Equipment	5.0	5.0	5.0	5.0	5.0	25.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code WFO:NIH).

Computational Cryo-Electron Microscopy

Continuing our leadership in molecular imaging, we propose to develop the software technology needed to greatly accelerate the determination of the atomic structures of macromolecular assemblies. Using electron microscopy, a great number of images are needed to achieve the signal-to-noise ratio required for high-resolution structure determination. For example, a data set of approximately 100,000 asymmetric units can produce a three-dimensional reconstruction at 8 to 12-angstrom resolution. Even larger data sets of at least one million asymmetric units are needed to achieve resolutions better than 5.0 angstrom, and to ultimately obtain three-dimensional reconstructions near 3.5 angstrom (the resolution needed for *de novo* determination of atomic structures).

With data sets of this size, new software tools must be created to rapidly complete the associated computational work. Our focus for creating this technology involves three steps: (1) adapting and optimizing single-particle analysis software for operation within parallel computing environments; (2) developing computer-assisted review of candidate particle image galleries, and (3) developing better algorithms to estimate the alignment parameters of single particles. Experimental images will be obtained for two macromolecular assemblies whose atomic structures are already known, and these reference data will be used for the development and validation of the new technology this project creates. In conjunction with automation efforts like those at the ALS, this work promises to greatly increase our library of known macromolecular proteins.

Computational Cryo-Electron Microscopy Resource Requirements ($M)

	2004	2005	2006	2007	2008	Total
Operating/Equip	1.9	1.7	1.7	1.8	1.9	9.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code WFO:NIH).

Decoding Animal Genome Sequences

The genome sequences of many species—including our own—provide a rich treasure trove of information; they are quite literally “blue prints for life.” But especially for the complex genomes of animals, we cannot interpret the majority of this sequence information. Much of this currently uninterpretable DNA is thought to code for the binding sites of regulatory transcription factors, for mRNA splice signals, and for proteins determining the higher order structures and movements of chromosomes. Berkeley Lab proposes a series of interdisciplinary projects, in collaboration with the Joint Genome Institute, to learn how to interpret this information.

The main limitation holding back progress has been the lack of techniques and strategies for generating and analyzing the large amounts of data required to study such massive, complex problems. To overcome this limitation, teams of doctors, biochemists, geneticists, bioinformaticists, engineers, and imaging physicists will be employed in four areas. One area will focus on the gene network associated with cardiovascular disease, cholesterol, and lipid metabolism in humans and mice. A second will make use of the powerful genetic and other techniques available in the fruit fly to make a fundamental study of an entire gene expression network. A third seeks to decode the regulatory elements in the human genome that precisely regulate tissue-specific alternative pre-mRNA splicing. The fourth examines the structures of centromeres and sequences controlling chromosome pairing in meiosis in *Drosophila* and *C. elegans*.

Using the outstanding capabilities of this national laboratory, we will establish novel biochemical and genetic protocols, automate processes, build new devices, and develop new algorithms and databases. This project will synergize well with DOE's Genomes for Energy and the Environment: Genomes to Life initiative, especially with the proposal to develop a high-throughout facility to analyze protein complexes. The dynamic combinatorial interactions between proteins as they bind nucleic acids determine rates of transcription, mRNA splicing patterns, and chromosome structure. A facility that can characterize these interactions on a large scale will be invaluable.

Decoding Animal Genome Sequences Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	9.3	9.6	9.9	10.2	10.5	49.5
Equipment	0.6	0.6	0.6	0.6	0.6	3.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code WFO:NIH).

High Throughput Structural Biology

A long-range technical goal for structural biology at synchrotron x-ray sources is to achieve maximum automation of tasks currently carried out manually when performing diffraction experiments on synchrotron beamlines. We continue to develop hardware and software for automating the manipulation of single crystal protein samples, which will form the basis of a completely automated synchrotron beamline data collection system. Our ultimate goal is to construct at the Advanced Light Source (ALS) the integrated beamline system that is capable of loading, centering, optimally collecting, and processing data on crystals of biological molecules with dramatically reduced human intervention than is currently available. These systems could be further utilized at other crystallography beamlines to increase throughput and productivity. The development of intelligent and autonomous control of the experiments will be explored after the modular tasks of data collection, beamline control, and data processing are achieved to provide a system for automated and optimized data collection. Scientific efforts are to extend the size and complexity of the biological molecules for which high-resolution structural information is available, as well as to provide a "taxonomy" of protein motifs within structural genomics.

We are now developing software technology for automated crystal screening and data collection at the ALS. This will provide a novel and robust solution to the problem of automated data collection. We will combine new and existing software tools in a hierarchical system that makes use of the robotic hardware and advanced beamline control software available at the ALS. The system will automate the processes of crystal screening, quality assessment, data collection and processing, and finally structure determination. Without the appropriate software tools for automated data collection, the current inefficiencies that result from human error will persist and rapidly become the dominant bottleneck in the structure solution process.

We are also developing the automation of ALS beamline 4.2.2. One goal is to provide the software for automated data collection and structure solution. This will be achieved by the deployment of automated software, and the development of high-throughput methods for experimental phasing. The optimal application of anomalous diffraction methods and real-time monitoring of the experiment will be used to help researchers rapidly obtain high-quality data. Of particular importance for this work is the availability of beamtime for extensive tests of different experimental approaches to data collection.

High Throughput Structural Biology Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating/Equipment	2.4	2.3	2.3	2.3	2.7	12.0

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code WFO:NIH).

Molecular Machines for Maintaining Genomic Integrity

A major challenge for the future is to integrate cellular function as understood through molecular cell biology of complex processes with structure at escalating levels of complexity from protein domains to large multiprotein molecular machines to coordination and regulation of these machines in the cell. One of the most fundamental cellular functions is the necessity of maintaining genomic integrity in the face of continuous genotoxic stress from cellular metabolites and environmental agents. The high-fidelity replication and repair of the genome is a prerequisite for maintaining cellular function and for transmission of genetic information to the next generation, and an intricate network of DNA repair processes combines to safeguard the integrity of the genome. This highly complex network of interacting molecular machines provides an excellent paradigm for other fundamental chromatin-associated cellular processes as well, including transcription, replication, and recombination. Our understanding of DNA repair mechanisms is based upon a long tradition of pioneering work funded by OBER and its predecessors, and it is thus highly appropriate that study of the assembly, structure, function, and cellular coordination of molecular machines for maintaining genomic integrity be integrated with the Genomes to Life initiative.

It is now clear that cells regulate genes and gene products at every level possible: chromatin structure, transcription, mRNA splicing and stability, post-translational protein modifications of many types, subcellular localization, and dynamic protein assemblies. To understand such complexity, major initiatives at Berkeley Lab are addressing the challenge of what can be termed “structural cell biology” of DNA repair by building upon strengths and unique resources in Life Sciences, Physical Biosciences, the Advanced Light Source, and Engineering, and linking them with major NIH-funded research efforts in DNA repair and damage responses both at Berkeley Lab and by academic collaborators from many major universities. Techniques and facilities are being developed to bridge the size and resolution gap between x-ray diffraction structures of separate proteins, electron microscopy of biological assemblies, and dynamic subcellular localization of these assemblies in order to advance the interpretative framework for molecular and cellular biology. These initiatives will integrate the currently separate powerful technologies of protein mass spectroscopy, single-particle electron microscopy, x-ray scattering in solution, electron and x-ray tomography, high resolution x-ray diffraction, and live cell imaging to provide structural and functional information on critical DNA repair complexes and their cellular regulation.

A joint effort of the Office of Science and the National Cancer Institute (NCI) of NIH is providing development and application of a structural cell biology synchrotron beamline at the ALS that has been purpose-designed for integrated studies of multiprotein complexes. Design and construction (to be completed by early FY 2004) of this tunable wavelength beamline, named SIBYLS for **S**tructurally **I**ntegrated **B**iolog**Y** for **L**ife **S**ciences, was funded by OBER in FY 2001, and a proposal will be submitted to OBER for its operation. Specialized instrumentation for SIBYLS and development of its versatile applications for understanding DNA repair processes is being provided by NCI as part of a multi-institution project on Structural Cell Biology of DNA Repair Machines (SBDR) centered at Berkeley Lab. SIBYLS is optimized for large unit cells, small crystals, and the collection of very low to very high resolution diffraction data that are key to solving large complexes. Furthermore, it will allow small angle x-ray scattering (SAXS) in solution to characterize conformational changes, and to validate the crystallographically defined conformational states for DNA repair complexes. SIBYLS will provide unique capability for structurally defining flexible regions of large protein complexes, and the means to relate them to electron microscopy reconstructions. It will provide the technology to support experiments designed to allow docking crystal structures of component proteins into the electron density of the larger, multicomponent biologically relevant states, some of which cannot be crystallized (such as some intermediate assembly states), and will thus provide detailed structural data for large complexes, including regions that undergo functionally important conformational changes. It is expected that SIBYLS will provide a unique capability in structural biology of molecular machines that does not presently exist at any other facility worldwide.

The unique capabilities of the SIBYLS beamline are a centerpiece of the NCI-funded program project in SBDR, which integrates multi-institutional studies on multiple DNA repair processes in mammalian cells through core capabilities in Life Sciences in structural biology, protein expression, and analysis of protein-protein and protein-DNA interactions. Additional new initiatives are being developed for NCI funding as SBDR satellite programs in advanced mass spectrometry analysis of dynamic multi-protein complexes formed in the cell, integration of dynamic changes in chromatin organization with DNA repair processes, and advanced understanding of signaling processes for regulation of DNA damage responses. In addition, while the assembly and organization of "molecular machines" is being addressed with sophisticated structural and biochemical techniques, there is a clear need to understand how these assemblies and component proteins are spatially and temporally orchestrated within the cell. A new initiative will exploit advances in microscopy and recombinant technologies that allow for the fusion of cellular proteins with the green fluorescent protein (GFP), and facilitate dramatic real-time observation of the molecular localities, organization, and dynamics of proteins, and processes in the cell. Many DNA repair proteins are already known to rapidly relocate to the site of DNA damage and there assemble into molecular machines. By fusing different DNA repair proteins with GFP, real-time observations of the subcellular localization of these molecules in response to DNA damage can be made through live cell microscopy with confocal time-lapse imaging coupled to quantitative fluorescence assays such as fluorescence recovery after photobleaching (FRAP) and fluorescence resonance energy transfer (FRET). An initiative to develop these powerful new tools will allow us to directly observe the mobilization, assembly, and function of DNA repair machinery within the cell in response to genomic insult. Berkeley Lab has established state-of-the-art microscopy and imaging facilities, and the addition of these new capabilities would significantly enhance the research environment and add exciting possibilities for studying these essential repair processes in the most relevant of contexts, within the cell.

It is important to note that, while these NIH initiatives are directed toward understanding molecular machines for maintenance of genomic integrity in mammalian cells, they will be highly synergistic with related efforts to understand structure, function, and integration of molecular machines in microbial systems through the OBER Genomes for Energy and the Environment: Genomes to Life initiative.

Molecular Machines Resource Requirements ($M)*

	2004	2005	2006	2007	2008	Total
Operating	3.5	3.6	3.8	3.8	4.0	18.7

*Preliminary estimate of Berkeley Lab Budget Authority (B&R Code WFO:NIH).

V. OPERATIONS STRATEGIC PLANNING

Berkeley Lab's Operations strategic planning focuses on aligning the Laboratory's administrative and support systems to the needs of the program scientists who conduct DOE national research programs. These efforts are directed at providing the services to help deliver scientific results and support the achievement of Berkeley Lab's Scientific Vision (see Section III). A number of organizational systems have been identified as critical factors for Berkeley Lab's efficient and effective performance. These systems directly support DOE's strategic science objectives and the conduct of research in a safe and secure manner, protecting employees, DOE assets, the public and the environment. The Operations planning efforts, currently underway are directed towards achieving the Operations Vision:

- Berkeley Lab will be the best place in the world to conduct scientific research. Our effective and efficient infrastructure, systems, engineering, and health and safety programs will be world class.
- We will be part of a unified Laboratory, where the full contribution of every individual is expected, respected and recognized. Working across organizational boundaries, we will develop new synergies that deliver effective innovative solutions. We will appreciate and benefit from our diversity. Our environment will be rich with opportunities and we will be challenged to grow to our fullest potential.
- We will have constructive relationships with and be trusted by our sponsors, neighbors, and collaborators. We will cultivate relationships with competence, integrity, and openness. Our partnerships will open new opportunities to serve our communities, the nation, and the world.

The Operations strategic planning efforts are directed toward improving management and systems during a multiyear effort, with a focus on four important areas:

- **Operational Efficiency and Effectiveness.** Integrate best business practices to provide efficient and effective operational support to the scientific mission of the Laboratory.
- **Infrastructure Enhancement.** Improve facilities and our engineering and information technology systems to support the current and future programs of Berkeley Lab.
- **Employee and Leadership Development.** Improve individual and organizational effectiveness while creating a motivating work environment that attracts and retains high-caliber employees.
- **External Relations.** Build constructive and supportive relationships with constituent groups and improve the understanding of the Lab within the community.

Initial actions that have been implemented include a new employee Performance Review and Development process; a new Activity-Based Budgeting system for indirect cost management, revisions to the Laboratory's Comprehensive Planning Calendar, and an analysis of the Laboratory's recharge system.

ENVIRONMENT, SAFETY, AND HEALTH

Integrated Safety Management

Berkeley Lab's Integrated Safety Management System (ISMS) fully supports DOE's strategies for assuring the safety and health of workers and the public, and the protection of the environment. The EH&S (Environment, Health, & Safety) Division strives to make Berkeley Lab's ISMS, a model program within the DOE complex in terms of both ES&H performance and professionalism. A strong ISMS makes Berkeley Laboratory competitive, and gives assurances that:

- Scientific creativity will enable new discoveries while scientific discipline ensures research is done safely.

- ES&H issues will be given priority with full consideration given to building ES&H into research objectives and schedules.
- Assets at Berkeley Lab will be well protected.

A constructive partnership between Berkeley Lab and DOE's Berkeley Site Office (BSO) has led to one of the most effective ES&H oversight models within the DOE complex—Operational Awareness. Throughout the year, Operational Awareness has replaced traditional annual inspections with increased BSO involvement in Lab activities. It also included progressive contract performance measures with both leading and lagging indicators. These performance measures have demonstrated the high level of effectiveness of the Operational Awareness program. FY 2003 marked a new direction for Berkeley Lab's ES&H program based on Undersecretary Card's memo of April 30, 2002, wherein he articulated the following principles for Berkeley Lab's new contract:

- **Line management accountability**: Contractors need a clearly defined DOE Field Manager to whom they are accountable for both scientific and operational performance.
- **National standards**: DOE will minimize the number of DOE-unique requirements, relying primarily on national standards and federal, state, and local laws and regulations.
- **Oversight**: DOE will use external experts to validate and certify contractor commitments to improve effectiveness, efficiency, and accountability.

In support of the Under Secretary's principles, and again using the strong partnership with BSO, the Laboratory negotiated new ES&H performance measures for FY 2003. The measures created milestones for considering and, where appropriate, attaining national certifications and third-party validations for each of the programs in EH&S. Currently, the Lab is pursuing certifications and validations that include:

- Occupational Safety and Health Association (OSHA) and DOE Voluntary Protection Program
- Third-party validations of an Environmental Management System (EMS)
- Accreditation by the Emergency Management Accreditation Program
- Accreditation Association for Ambulatory Health Care
- Self-Assessment System Certification using the Institute of Nuclear Power Operators (INPO) Guidelines on Self-Assessment and Corrective Action.

These are in addition to other accreditations already in place such as DOE Laboratory Accreditation Program (DOELAP) and Association for Assessment and Accreditation Laboratory Animal Care (AALAC).

Berkeley Lab will become even more competitive and aligned with industry standards and practices. It is also important to recognize the alignment of this strategy with Office of Science strategic planning goals. With efficient DOE oversight that will come from certification/validation to national standards, the Office of Science's investment in Berkeley Lab will be enhanced. Streamlined operations will come from fewer DOE-unique standards where industry standards are fully adequate, and from Lab accountability to a single DOE manager.

As in years past, Berkeley Lab sustains a strong environmental program with many key elements. Among these are programs in waste management, air/water quality protection, pollution prevention, waste minimization, and environmental restoration. All performance measures (internal Self-Assessment, Contract Performance Measures, Office of Science ES&H Reporting Metrics) show outstanding performance.

In FY 2003, Berkeley Lab successfully integrated the waste management program into institutional funding after DOE withdrew program funding from both Environmental Management (EM) and Office of Science (SC). This was a major accomplishment. A looming challenge is the transition of the restoration program from an EM-managed and -funded activity. (A more detailed discussion is in Section VII, Summary of Major Issues.)

COMMUNICATIONS AND TRUST

Information Management

The purpose of Berkeley Lab's information technology infrastructure (IT) is to provide the Laboratory with efficient, effective, and innovative information technologies and services to enable world-class science. The range of services provided encompasses virtually all areas of modern computing and communications technology with the exception of large-scale scientific computing. Berkeley Lab's strategic plan for IT infrastructure defines an integrated approach that builds upon the substantial technology benefits that the Laboratory has realized during the past decade, and incorporates the modern technologies needed by the Laboratory to remain at the forefront of scientific research.

The major infrastructure services are:

- Scientific Computational Services (e.g., midrange computing, visualization)
- Productivity Services (e.g., email, desktop computing)
- Information Services (e.g., information systems, library)
- Presentation Services (e.g., publishing, conference tools)
- Protection (e.g., intrusion detection, firewalls, backups and archiving)
- Networking and Telecommunications (e.g., networking, telephones, remote access)
- Service Delivery Architecture (e.g., technical architecture, cost recovery, Integrated Safeguards and Security Management (ISSM))

The majority of activities in each of these areas are ongoing production services. The largest strategic challenge faced is sustaining the effectiveness and dealing with the growth of these services.

There are a number of specific requirements driven by user needs and technological opportunities that demand new or improved services categorized in the following major areas:

- Modernize aging infrastructure to increase science and business productivity, including reinventing library services and enhancing scientific computing support, "productivity" tools, and network infrastructure.
- Improve the utility of administrative systems through development of an integrated information portal to support timely decision making at all levels of the Laboratory's operations.
- Improve the IT technical architecture to help assure that the Information Technology and Services Division's (ITSD) resources are being directed in a consistent, cost-effective manner, and to help assure that Berkeley Lab is achieving maximum benefits from its IT investments.
- Establish and provide appropriate levels of protection, recovery, and continuity for all of the Laboratory's critical IT systems and data.

Meeting these challenges is particularly difficult in view of the rapid technology advancements and obsolescence that characterize IT functions. This impacts both the need to enable the Lab to benefit from substantial ongoing improvements in computer and communications hardware and software, and the need to continually develop high-quality staff who remain up to date with this technology.

Community Relations and Public Communications

A key element of the Laboratory's strategic planning includes the strengthening of communications and involvement at all levels, both internal and external, in order to build trust with the public and Berkeley Lab employees. This emphasis parallels DOE's goal to maintain a culture of openness, communication, and trust. Community relations has been an important element of Berkeley Lab strategic planning and is integral to the Operations Vision and strategic planning for FY 2003 and beyond. The Laboratory has taken many steps to enhance community interaction and understanding, including a fire services agreement with the City of Berkeley, and implementing a community-developed vegetation management plan. An ongoing speakers' bureau and tour program provides continued outreach to the breadth of community stakeholders. Berkeley Lab also participates in community-sponsored activities like science education and energy use reduction programs, offering the Laboratory's expertise and in-kind support.

Communications with local government, regulatory agencies, citizens' groups, schools and educational institutions, the news media, and other stakeholders require regular interactions between Berkeley Lab and community members. The purpose of these activities is to consider and respond to the interests of specific groups, including elected officials, opinion leaders, city staff, site neighbors, and employees. Activities have included briefings for elected officials, attendance at local community meetings, sponsorship of meetings with the public, speakers at local events and organizations, as well as tours of Berkeley Lab. In addition, through the National Environmental Policy Act and California Environmental Quality Act (NEPA/CEQA), and other federal and state regulations requiring public involvement, Berkeley Lab works with these stakeholders to disseminate information and solicit public input. This includes input into the environmental review process for proposed Berkeley Lab projects and actions. Berkeley Lab values its relations with local communities and is committed to an expanding outreach effort.

An Open House, a biannual event staged most recently in the Fall of 2002, brings the messages of the possibilities in science education and careers, the value of research, and the DOE missions to thousands of visitors and stakeholders in the Bay Area. Berkeley Lab employees make additional commitments to their communities through participation in numerous local Councils, Boards and Commissions, and through an annual charitable giving campaign. Berkeley Lab will continue to promote two-way interactions between management and the workforce through training for Berkeley Lab leadership, increased opportunities for employee development and feedback, and other communication mechanisms and programs.

MANAGEMENT PRACTICES

Human Capital Development

Effective human-resources development activities are critical to the success of Berkeley Lab's programmatic initiatives. The Human Resources (HR) mission statement is "to act as a partner by providing Human Resources programs, services and support to the people of the Berkeley Lab to enable them to perform the strategic, scientific, and operational mission of the Laboratory."

The objectives of the Human Resources Department are to:

- Promote human resources practices that contribute to making Berkeley Lab a great place to work and the best place to do science.
- Champion programs and services that support a work environment where diversity, and individual and team contributions are expected and valued.

- Develop and sustain collaborative relationships with our customers, sponsors, and partners that assure their confidence in our programs and services.
- Advocate a culture that values employee development, and where learning crosses organizational boundaries through adaptive practices, systems, and processes that encourage teamwork, creativity, and discovery.

To support the Laboratory's mission, the Human Resources Department has established the following four strategic goals:

- **Recruitment**—To establish recruitment programs, systems, and support services that enable the Laboratory to attract and retain an outstanding and diverse scientific and operations workforce.
- **Work Climate—**To establish programs and services that support and engage a diverse employee population in all aspects of the work environment.
- **Employee and Leadership Development**—To partner with divisions to create a continuous learning environment, and to identify and establish employee and leadership development programs that enable the Laboratory to fulfill its scientific mission.
- **Continuous Improvement—**To streamline and continuously improve HR policies, systems, and processes so the Laboratory is able to meet its strategic scientific and operational objectives efficiently and effectively.

The Human Resources Department continues to work with the Workforce Diversity Office to support and develop outreach recruitment programs, and to expand our efforts to create a climate in which diversity in the workforce is valued.

A significant effort that started in September 2002 has been to create a certified Human Resources Management System based upon the DOE Office of Science principles of Line Management Accountability, National Standards, Oversight, Contractor Accountability, Vision, and Incentives. Components of the certified system will consist of standards, self-assessment against the standards, certification, and peer review. We are working closely with the University of California Office of Laboratory Administration and the Department of Energy on establishing the certified system.

Best-practice national standards for self-assessment will be established for the following areas:

- Recruitment: System Metrics and Diversity
- Retention: Compensation and Employee Satisfaction
- Development: Performance Management and Competency Improvement
- Labor and Employee Relations: Work Climate and Labor Union Contract Management

As a formal certifying body does not exist for Human Resources, we have started an exciting dialogue with the Human Resources Certification Institute (HRCI), which currently certifies individuals but not organizations.

Table V (1) Laboratory Staff Composition (FY 2002)

Full & Part Time Employees	Total		PhD		MS/MA		BS/BA		Other	
Scientists*	24%	910	88%	797	5%	41	3%	24	5%	48
Faculty	7%	258	95%	245	2%	4	0%		3%	9
Professional*	16%	616	14%	87	27%	168	33%	203	26%	158
Executive	0%	7	100%	7	0%		0%		0%	
Administrative	16%	610	3%	21	16%	95	32%	194	49%	300
Technical	23%	855	2%	21	10%	87	22%	192	65%	555
All Other	14%	513	1%	5	13%	68	47%	243	38%	197
Grand Total		3769		1183		463		856		1267

* Berkeley Lab has made significant changes in its job family structure as related specifically to the former classification for "Engineers." This classification has been supplanted by Berkeley Lab's current "Scientists" and "Professional" classifications.

Workforce Diversity

With workforce diversity being an integral part of senior management's vision, Berkeley Lab took significant steps during FY 2001 toward its recommitment to diversity—a recommitment notable for its actions toward instilling diversity as a value and practice throughout the Laboratory. All levels of management and staff are now involved in diversity awareness and recruitment, and in making Berkeley Lab a research organization that is welcoming and productive for all employees. Affirmative action programs and inclusive recruitment efforts that include specific metrics are a part of the Self-Assessment Section on Human Resources. This new diversity performance measure focuses on leadership and awareness.

Workforce Diversity Plans

Customized diversity action plans were to be critical to each division director's diversity-management goals. As a key follow-up to these activities, Director Shank formalized the new diversity activities in two significant ways: (1) instituting the Laboratory Diversity Performance Measure 1.1.e, and (2) adding diversity management to the performance criteria of division director job expectations. In addition, senior management's collective responsibility for diversity was made evident in the Division Director job description, which includes the following: "Enhance cultural diversity among your workforce and actively pursue plans and programs to incorporate effective affirmative action activities. Develop a Divisional Diversity Plan for review by the Director on an annual basis. Serve as a model for providing equal employment opportunities in the recruitment, assignment, and development of personnel."

In addition, in order to enhance diversity and an inclusive work environment, senior management concluded that the collective movement of all divisions and departments toward diversity must follow diversity best practices. The Laboratory's diversity best practices incorporate the following principles:

- Leadership and awareness
- Employee involvement
- Strategic planning
- Evaluation and measurements
- Linkage to organizational goals and objectives

The diversity best-practices model was built around these principles in order to create a process that conveys a shared understanding of diversity's importance.

Progress on Action Plans

Division directors submitted a calendar-year 2002 diversity action plan summary for the Laboratory Director's and Deputy Directors' joint review and critique. Division directors then used the Director's comments to refine their plan, forming a systematic approach suitable to their specific division's needs. Every division director prepared a final plan for review and approval. Also, four Operations Area Department Plans were approved (Administrative Services, Financial Services, Facilities, and Human Resources Departments).

By early calendar year 2002, divisional diversity action plans were approved for publication on the Diversity Action Plan Web Site (http://www.lbl.gov/Workplace/WFDAP/). The site illustrates the wide variety of diversity issues faced by Laboratory management across Berkeley Lab, and the specific actions used to improve workforce diversity.

All plans addressed two main elements: innovative actions to enhance the work environment for all employees, and methods of assuring hiring pools that are as diverse as possible. Each customized diversity plan mirrors the unique needs and concerns of a division or a department. There are five categories (Diversity Recruitment, Training and Education, Diversity Outreach, School-to-Career Partnerships, and Pipeline Mentoring) that represent the variety of diversity tools available to senior management, and illustrate the wide variety of divisional diversity actions throughout the Laboratory.

In FY 2002, Berkeley Lab instituted the following Performance Development Review expectation to reinforce its commitment to diversity: "Employees at all levels of the organization are expected to work effectively within our diverse culture by promoting and supporting an environment in which all employees are valued, respected, and included. Managers and supervisors have the additional responsibility to enhance this development by modeling and sustaining the commitment among team members and staff."

Laboratory senior management approved the Diversity Best Practices Council (DBPC) in FY 2003. The Council was formed to provide a forum for council members to leverage and implement diversity best practices and processes in their divisions, while integrating the Laboratory's diversity initiative as a whole. The foundation of the Laboratory's diversity initiative rests on the achievement of the following goals and objectives:

- Foster an inclusive work environment that fully recognizes the contributions of all employees.
- Build a workforce that reflects and embraces the diversity of our community.
- Create synergy between division/department diversity action plans and initiatives.
- Develop a diversity best-practices framework and grow best practices models across the Laboratory.
- Mentor new initiatives and welcome the views of outside speakers.
- Visibly recognize and communicate diversity best-practices achievements throughout the Laboratory.
- Identify and address emerging issues and develop a Lab-wide diversity scorecard.

Berkeley Lab's action plans and performance measures represent the Laboratory's recommitment to a workplace of diversity, accountability, and open communication. Its prominence in the scientific community, its partnership with DOE, and its commitment to being an employer of choice require Berkeley Lab's continuing leadership in workplace diversity.

Table V (2) Equal Employment Opportunity (FY 2002)

Federal Occupational Category	Total Male	Total Female	Caucasian Male	Caucasian Female	Minority Total Male	Minority Total Female	Black Male	Black Female	Hispanic Male	Hispanic Female	Native American Male	Native American Female	Asian/Pac. Isl. Male	Asian/Pac. Isl. Female
OFFICIALS & MANAGERS	92	42	74	39	18	3	4	1	7	0	0	0	7	2
	54.44%	24.85%	43.79%	23.08%	10.65%	1.78%	2.37%	0.59%	4.14%	0.00%	0.00%	0.00%	4.14%	1.18%
Total Male and Female	134		113		21		5		7		0		9	
	100.00%		84.33%		15.67%		3.73%		5.22%		0.00%		6.72%	
PROFESSIONALS														
Scientists/ Engineers	1063	317	809	218	254	99	30	11	27	15	3	2	194	71
	85.59%	25.52%	65.14%	17.55%	20.45%	7.97%	2.42%	0.89%	2.17%	1.21%	0.24%	0.16%	15.62%	5.72%
Total Male and Female	1380		1027		353		41		42		5		265	
	100.00%		74.42%		25.58%		2.97%		3.04%		0.36%		19.20%	
Management/Administrative	48	167	36	107	12	60	4	17	1	11	0	1	7	31
	21.76%	21.76%	21.76%	21.76%	21.76%	21.76%	21.76%	21.76%	21.76%	21.76%	21.76%	21.76%	21.76%	21.76%
Total Male and Female	215		143		72		21		12		1		38	
	100.00%		66.51%		33.49%		9.77%		5.58%		0.47%		17.67%	
TECHNICIANS	240	54	167	26	73	28	18	5	21	6	0	2	34	15
	65.40%	14.71%	45.50%	7.08%	19.89%	7.63%	4.90%	1.36%	5.72%	1.63%	0.00%	0.54%	9.26%	4.09%
Total Male and Female	294		193		101		23		27		2		49	
	100.00%		65.65%		34.35%		7.82%		9.18%		0.68%		16.67%	
CLERICAL	37	192	16	86	21	106	7	69	4	16	3	0	7	21
	15.10%	78.37%	6.53%	35.10%	8.57%	43.27%	2.86%	28.16%	1.63%	6.53%	1.22%	0.00%	2.86%	8.57%
Total Male and Female	229		102		127		76		20		3		28	
	100.00%		44.54%		55.46%		33.19%		8.73%		1.31%		12.23%	
CRAFTSMEN/LABORERS	112	1	79	1	33	0	11	0	13	0	2	0	7	0
	88.89%	0.79%	62.70%	0.79%	26.19%	0.00%	8.73%	0.00%	10.32%	0.00%	1.59%	0.00%	5.56%	0.00%
Total Male and Female	113		80		33		11		13		2		7	
	100.00%		70.80%		29.20%		9.73%		11.50%		1.77%		6.19%	
SERVICE WORKERS/	33	16	6	5	27	11	15	5	9	4	0	0	3	2
APPRENTICES	34.38%	16.67%	6.25%	5.21%	28.13%	11.46%	15.63%	5.21%	9.38%	4.17%	0.00%	0.00%	3.13%	2.08%
Total Male and Female	49		11		38		20		13		0		5	
	100.00%		22.45%		77.55%		40.82%		26.53%		0.00%		10.20%	
TOTAL ALL CATEGORIES	1625	789	1187	482	438	307	89	108	82	52	8	5	259	142
	66.03%	32.06%	48.23%	19.59%	17.80%	12.47%	3.62%	4.39%	3.33%	2.11%	0.33%	0.20%	10.52%	5.77%
Total Male and Female	2414		1669		745		197		134		13		401	
	100.00%		69.14%		30.86%		8.16%		5.55%		0.54%		16.61%	

Figures are based on end of fiscal year.

Security, Intelligence, and Nonproliferation

Berkeley Lab works to assure that its personnel and visitors are safe, and that its assets—intellectual, property, computational, and other resources—are properly protected to sustain its scientific mission and operational requirements. Berkeley Lab maintains and updates its Site Safeguards and Security Plan, which addresses potential threats and targets and describes the protection systems and strategies that are in place. These systems include protection strategies and physical protection systems; protective forces; material control and accountability programs; provisions for personnel, information, and property protection; and records and risk-assessment activities. Consistent with the Laboratory's approach to integrated management of support operations, Berkeley Lab developed an Integrated Safeguards and Security Management (ISSM) program. The approach ensures the integration and coordination of all elements of security, including physical, cyber, export control, information management, and related aspects.

As indicated in Section II of the Institutional Plan, Berkeley Lab's role is in fundamental research and development—the research subject areas are generally available in the public domain with civilian science purposes and aligned to university disciplines. Since it does not have classified research on site or classified information files or facilities, the Laboratory had been designated as an exempt laboratory for DOE's unclassified Foreign Visitors and Assignments Order (except for hosts with clearances—see below). This exemption was rescinded for all Tier III Labs on December 17, 2002. Nevertheless, Berkeley Lab participates in the operational framework of the national laboratory system, and with security considerations similar to other nonclassified facilities such as Stanford Linear Accelerator Center and Fermilab. The Laboratory is fully committed to the protection of important information, including export-control information, personnel information, financial information, computer operations, as well as site protections for property and personnel.

The Laboratory implements physical-security programs appropriate for the protection of its employees and laboratory property. Intellectual property, including data obtained through industrial contracts such as Cooperative Research and Development Agreements and Work for Others, is reviewed for export-control sensitivity and for patent disclosure considerations. Berkeley Lab has an Export-Control Officer responsible for the Export Control Program. Export control activities include review of intellectual property and of instruments and technology that may be shipped off site. Procedures are addressed and reviewed through the relevant DOE orders and guides. The approved business practices and procedures will be formalized and disseminated through Berkeley Lab's *Regulations and Procedures Manual*.

The Laboratory cybersecurity posture is described in its Cyber Security Protection Plan (CSPP). Best business practices based on cost and risk, consistent with DOE orders and oversight procedures, are maintained, reviewed, and updated to prevent unauthorized access to its computer systems. Computing Sciences operational practices are aligned with Department of Commerce regulations for export control, including supercomputer access by foreign nationals.

The Laboratory has a designated counterintelligence officer, and has developed a Counterintelligence Program whose focus is on requirements for the approximately 65 staff who possess security clearances (these are held by other facilities, for work at other institutions). Security-cleared personnel attend required counterintelligence briefings and security-awareness training.

Berkeley Lab's cybersecurity program addresses the needs of all computer and networking systems, and is fully appropriate to systems that contain no classified information. The program is coordinated by the Computer Protection Program Manager, and includes centralized resources of personnel and monitoring equipment and a division-based network of systems managers. A program for Lab-wide awareness of security issues addresses all Berkeley Lab employees and guests. The Laboratory's cybersecurity software and internal firewalls are a powerful system for detecting network intruders, and have served as a model for other laboratories.

Intellectual Property Management

Intellectual property is created in the course of research at Berkeley Lab, and is managed for the benefit of DOE and Laboratory missions, and for the U.S. public under the applicable technology-transfer statutes. Intellectual property includes patentable inventions, copyrightable works (e.g., software), and tangible research products and biological materials. Intellectual property disclosures are made to the Patent Department, and evaluated and transferred to the private sector by the Technology Transfer Department—typically under license, option, bailment, or similar agreements. As with most other national labs and research universities, Berkeley Lab's technologies tend to be very nascent, and require substantial development by a private-sector company before any commercial product is likely to emerge; therefore, protection and management of the intellectual property is a key factor to successful commercialization and the realization of the benefit to the consumer. In FY 2002, Berkeley Lab reported 60 new inventions, filed 30 new, nonprovisional, U.S. patent applications, and had 31 U.S. patents issued. A total of 30 new commercial licenses and options were executed. These numbers are generally typical of those reported since the late 1990s. In addition, Berkeley Lab continued to expand its Web-based distribution of software, issuing more than 34,000 licenses for open source or other free Berkeley Lab software.

Berkeley Lab's Technology Transfer Department regularly develops and manages partnerships with the private sector to commercialize technology for the public benefit. In one exemplary licensing program, a multipronged partnering strategy has resulted in the successful deployment in FY 2002 of the next-generation building-energy-simulation computer program, EnergyPlus. Berkeley Lab developed the EnergyPlus software in collaboration with the University of Illinois at Urbana-Champaign, the U.S. Army Construction Engineering Research Laboratory, DOE's Office of Building Technologies, and others. Energy Secretary Abraham officially launched on April 21, 2001, the initial release of EnergyPlus, and by the end of September 2002, over 10,000 copies of EnergyPlus were downloaded by architects, engineers, students, building owners, and managers. Users seek to save money, reduce energy use, and improve indoor air quality by using EnergyPlus to calculate the impacts of different heating, cooling, and ventilating equipment and various types of lighting and windows. In an early example, in July 2002, groundbreaking took place for a new San Francisco federal office building designed using the EnergyPlus software. The EnergyPlus modeling tool contributed to nearly $9 million in energy costs savings projected over twenty years for the building, and was used to simplify the façade, saving an additional $1.5 million in construction costs. In addition to the thousands of end-user licensees, over 50 academic, research, and commercial entities have joined the EnergyPlus community as collaborative developers, agreeing to contribute their improvements for inclusion in EnergyPlus. Eight commercial companies have also purchased distribution licenses to incorporate EnergyPlus into commercial products for sale. In sum, Berkeley Lab successfully used various partnering mechanisms and distribution channels to support broad dissemination of technology.

Table V (3) Intellectual Property Management

Category	FY 2001	FY 2002	FY 2003 (est.)	FY 2004 (est.)	FY 2005 (est.)
Number of New Licenses*	35	30	35	35	35
License Income ($K)**	1,107	1,374	1,500	1,600	1,700
Software Disclosures	20	13	25	25	25
Invention Disclosures	77	60	60	65	70
U.S. Patent Applications***	23	30	35	35	40
U.S. Patents Issued	30	31	25	30	30

*Includes options

**Cash in only (i.e., not including fair market value of non-cash income). Also, does not include direct reimbursement of patent costs.

***Not including provisional or continuation patent applications

Fiscal Year 2002 saw income from licensing exceed $1,370,000, and continue a double-digit growth rate (approximately 24% in comparison to the FY 2001 income). We expect to see further strong growth as the program matures, based on the experience of comparable technology-transfer offices throughout the U.S. The Berkeley Lab allocates licensing income consistent with the DOE operating contract and University of California Regents policy, providing for the reimbursement of patent or other intellectual-property protection costs, then allocating a share to the inventor with the remaining going to the Laboratory for research purposes. The percentage share to the inventor is variable-based on the policy in effect at the University of California at the time the invention was disclosed, but ranges from 35 to 42.5% of the net income.

Table V (4) Distribution of Net* Licensing Income

	FY 1997 and Prior Disclosure (%)	FY 1998 and Subsequent Disclosure (%)
Inventor Payments	42.5%	35%
Research and Development	42.5%	65%
Education	0%	0%
Office of Research and Technology Applications Administration	15%	0%

* Gross income less cost of intellectual property protection such as patenting or copyright registration costs

VI. INFRASTUCTURE STRATEGIC PLANNING

A key Department of Energy (DOE) objective is to provide leading research facilities and instrumentation to expand the frontiers of the natural sciences. Mission performance is inextricably coupled to the assets that house and facilitate this research—buildings and infrastructure that are dedicated to and operated for science. Research at Berkeley Lab is directly tied to quality facilities and site improvements through a proactive building and utility maintenance program. Building and utility assets are managed so that researchers are able to obtain the maximum level of service from these assets. Research-driven requirements are coupled with knowledge of facility characteristics and needs to form the basis of Berkeley Lab's infrastructure strategic planning.

INFRASTRUCTURE AND CHANGING SCIENTIFIC ROLES

The scientific drivers and buildings identified in Berkeley Lab's infrastructure planning advance DOE missions and the Office of Science programs, principally for the Offices of Basic Energy Sciences, Biological and Environmental Research, High Energy and Nuclear Physics, Advanced Scientific Computing Research, and Fusion Energy Sciences. In addition, technology advancements made by the Laboratory support the Energy Efficiency and Renewable Energy Programs and the Office of Civilian Radioactive Waste Management and other elements of DOE. The programmatic drivers and research facility needs that must be incorporated into the planning for Berkeley Lab and DOE managers are summarized in this section. Berkeley Lab expects to develop the site to:

- Stimulate and foster a collaborative, world-class scientific work environment that attracts and retains highly qualified professionals.
- Accommodate flexible, state-of-the-art facilities and infrastructure appropriate to Berkeley Lab's research roles for DOE.
- Support the growing user community at the Laboratory's scientific facilities.
- Promote its unique setting and outdoor spaces to maximize opportunities.
- Welcome users, visitors, and neighbors in an enabling, efficient, safe, and attractive manner.

Mission requirements are difficult to achieve in buildings with infrastructure systems designed to support laboratory practices of the 1940s and 1950s. Modern standards for cleanliness and temperature control, and expectations of microscale tolerances are particularly challenging in older buildings, yet much of the work now being performed demands space of such quality. Building system upgrades are required in some buildings. In addition, some of the smaller, older structures are not cost-effective to upgrade, and need to be replaced in order to better address mission needs. In some cases, there is an additional benefit, as these smaller World War II-era structures occupy prime sites, sites that can efficiently accommodate four- and five-story buildings. Increasing the user density at these prime locations will also improve overall operating and scientific efficiencies.

Berkeley Lab's 82-hectare (200-acre) main site is immediately adjacent to the University of California (UC) at Berkeley. The main site encompasses 1.77 million gross square feet (mgsf). In 2003, there were 107 buildings of conventional construction and 53 trailers at the main site. Additional space on the UC Berkeley campus includes 75,000 net square feet (nsf), and 337,000 gsf are located in leased buildings in the cities of Berkeley, Oakland, and Walnut Creek (leased gsf includes 45,000 gsf of exterior warehouse space).

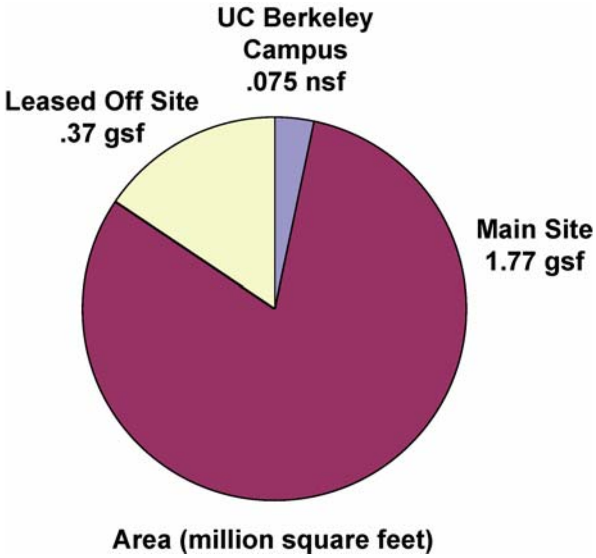

Figure VI (1) Laboratory Space Distribution

Berkeley Lab's scientific missions have changed since the first facilities were constructed on the current site for the 184-Inch Cyclotron and later, the Manhattan Project in the early 1940s. The challenge to the Laboratory in achieving its current multiprogram Office of Science mission is that more than 70 percent or 1.2 mgsf of the Laboratory's total current space was constructed prior to 1970, when the Laboratory was a single-purpose Atomic Energy Commission facility. The evolution of the Laboratory's programs is shown below.

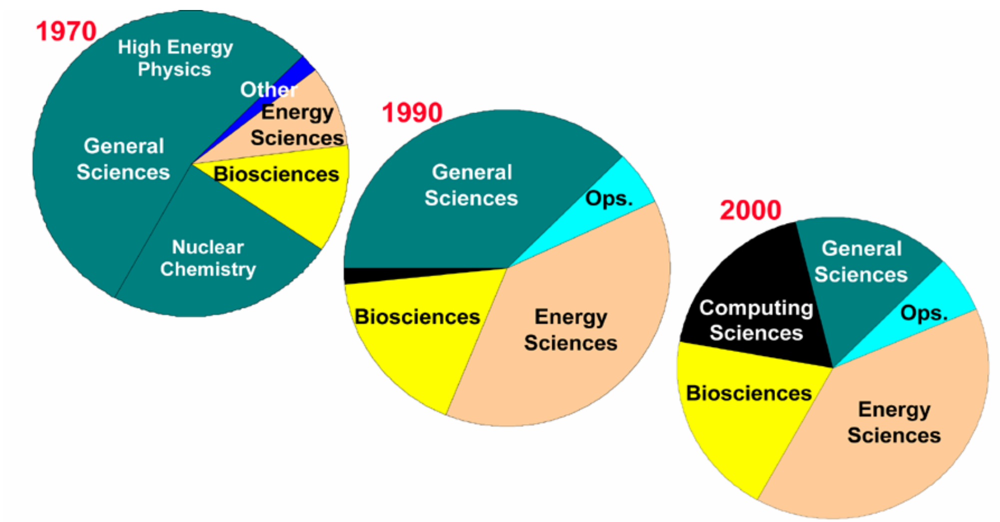

Figure VI (2) Change in Berkeley Lab Research Programs: Distribution of Research Funding

All usable space is fully committed to the scientific mission, and maintenance and administrative actions ensure that scientific needs are addressed. However, the World War II-era buildings are not suitable for most modern research programs. These facilities do not have the mechanical systems (e.g., air handling, heating, cooling, and plumbing) and electrical systems necessary to effectively and efficiently support most modern research. These building systems are vital to providing adequate cleanliness, fume removal, treatment, power, gas handling, and other operations necessary for experimental programs. In other instances, the buildings are not structurally satisfactory; some small buildings are condemned, and other buildings have occupancy limitations. Also of concern are buildings that were designed specifically for specialized functions that are no longer being conducted and that cannot be cost-effectively adapted for other uses. Use of unsatisfactory space is costly, and requires reliance on administrative controls to ensure that operational safety requirements continue to be attained. The average age of buildings at the Laboratory is now 37 years (weighted by square footage).

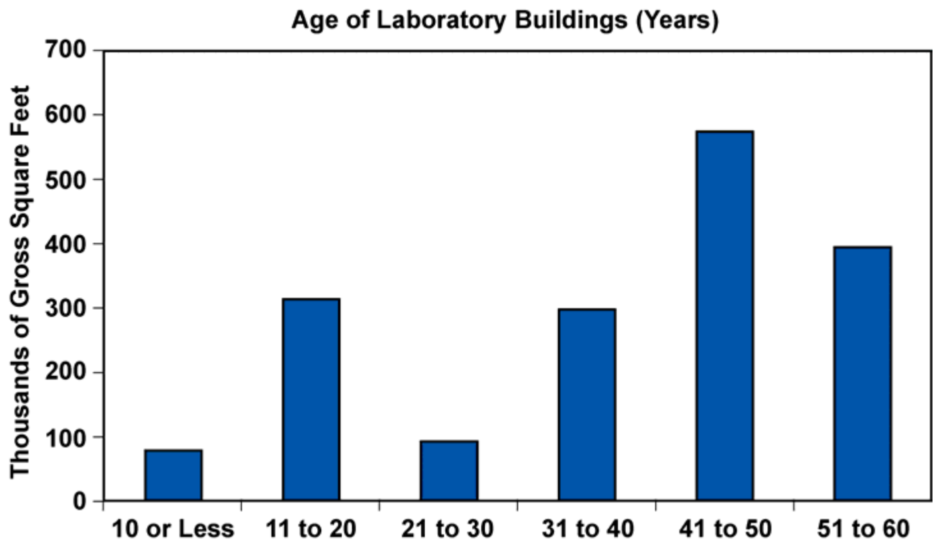

Figure VI (3) Age of Laboratory Buildings, Modulars, and Trailers

The most significant facility no longer serving DOE programs is the Bevatron, which encompasses 7.5 percent of the Laboratory's space and occupies a central location that should serve priority DOE missions, including those described below. Except for the Bevatron and SuperHILAC accelerator areas, and the buildings that have been shut down, all occupiable offices, laboratories, and support facilities at Berkeley Lab are 100 percent utilized.

The total replacement plant value (RPV) of active buildings and infrastructure is $890M [see Table VI (1)], as reported in the DOE Facilities Information Management System (FIMS). The value of the equipment in the buildings is $465M. On an annual basis, the Laboratory invests approximately $5M in noncapital projects in the buildings. The DOE Office of High Energy Physics has provided approximately $3.5M for General Plant Projects. The Science Laboratory Intrastructure (SLI) Program provides approximately $4M (based on the past 7 years). Collectively, these resources provide a 1.2 percent annual investment rate for active buildings and infrastructure, or a turnover time of approximately 100 years (excluding additional program construction funds).

Table VI (1) Facilities Replacement Plant Value (FY 2003)

Facility Type	Value ($Million)	% of Total
Active Buildings & Infrastructure	890*	72
Accelerators and OSFs	338	28
TOTAL	1228	100

* Building RPV includes property tracked in the FIMS database (incl. buildings and trailers), as well as leased properties. It does not include University of California campus space or programmatic buildings.

Building Conditions

Approximately 553,000 gross square feet (32%) of Berkeley Lab's space (at the main site) is substandard (rated Poor or Fail, includes buildings identified as "Excess" in FIMS) and in need of replacement. See Figure VI (4a). Existing research missions utilize much of this space, and much of it will remain in use pending replacement. If maintained well and updated where required, the vast majority — some 68% of the Laboratory's main site space — can continue to serve the research mission.

Demolition of WWII-era structures and special function facilities that cannot be cost-effectively reused remains a priority. The Building 51 complex, also known as the Bevatron, continues to be dismantled (it has been declared excess for several years). In addition, approximately 14 small buildings and trailers have been flagged as excess in FIMS and are identified for demolition; the majority of these buildings are currently vacant, some are "red-tagged," and others are in extremely poor condition. Furthermore, the Laboratory has identified a cluster of WWII-era facilities for near-term demolition. These "Old Town" structures do not meet most modern research requirements, are costly to maintain at some level of useable operating condition, and do not conform to modern codes and standards. This demolition program will also provide for the reuse of sites to construct modern buildings in order to address pressing requirements.

Space is at a premium, and capabilities must be increased in order to reduce overcrowding. Figure VI (4b), illustrates that 78% of computer space, 75% of wet lab space, and 63% of dry lab space are rated as functional (Excellent, Good, Adequate, or Fair) in 2003. Berkeley Lab must also continue to upgrade functional facilities that are not rated as "Excellent" to ensure that they continue to meet research needs and applicable health, safety, and environmental standards.

An evaluation of the various subsystems of each building was conducted this last year to more accurately detail rehabilitation and modernization costs. As a result, approximately 20% of the buildings previously rated as "Good" or "Adequate" were determined to be "Fair." Normal operating/maintenance costs are not included in these calculations.

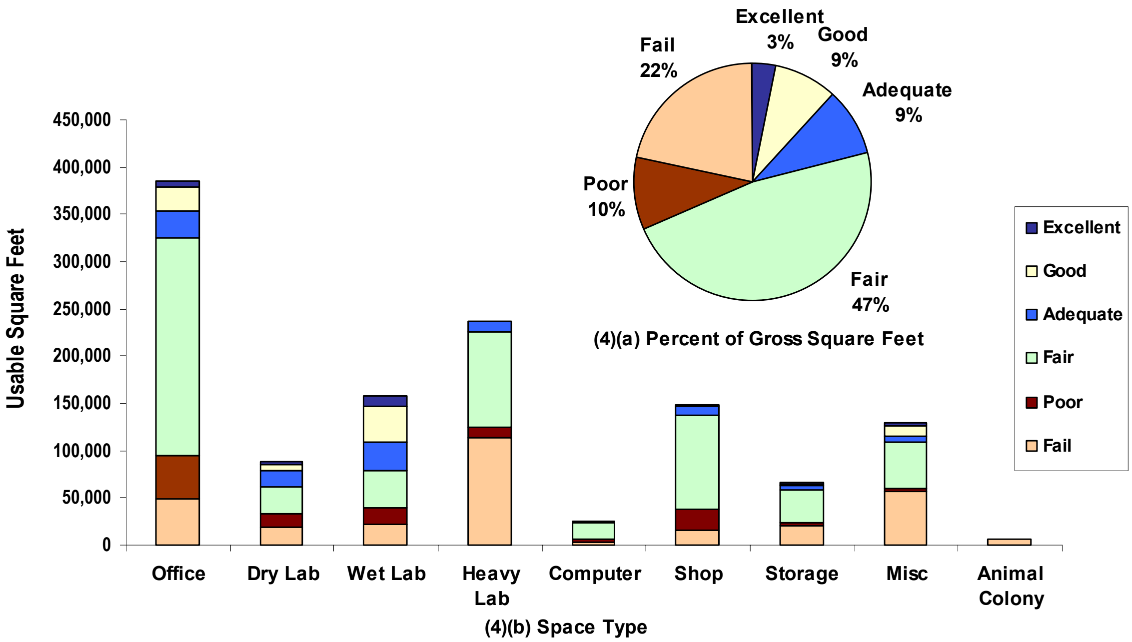

Figure VI (4) Use and Condition of Berkeley Lab Space

Required maintenance is identified through Condition Assessment Surveys conducted by an independent consultant. Their findings, along with cost estimates, are prioritized and entered into five-year and ten-year maintenance plans. Maintenance that is not performed when scheduled is then categorized as Deferred Maintenance. Actual maintenance costs are accumulated through the Maximo Work Order tracking system.

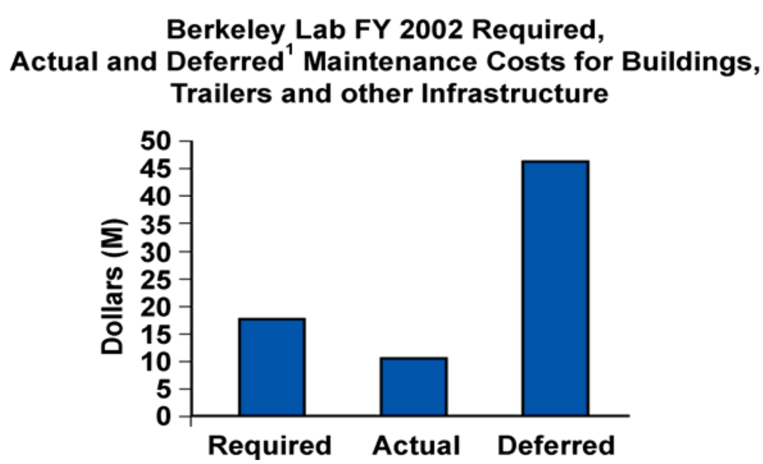

Figure VI (5) FY 2002 Maintenance Costs and Needs

[1]The deferred maintenance figure in this graph includes maintenance costs as reported to DOE by the Laboratory's Maintenance Group and as reported in FIMS. As a result of the Five-Year Inspection Cycle, Deferred Maintenance increased from $29M in FY01 to $46M in FY02 because of the deficiencies revealed during this year's inspections.

The Laboratory has 53 trailers at the main site. The Laboratory's Long Range Development plan calls for the removal of trailers and their eventual replacement by more efficient buildings of conventional construction. During the past five years, seven small trailers have been removed from the site due to their advanced stage of deterioration.

Off-Site Leasing

The Laboratory's historic trend in space has been an average increase of 30,000+ square feet a year. Over the past five years the increase to the total square footage has been a flat trend. The last building completed at the Laboratory was Building 84 with 55,000 gsf in 1997. The Laboratory has continued to meet DOE's mission requirements over the past five years, but has done so through increasing density and leasing offsite space. These two recent trends need to be reversed; the *Strategic Facilities Plan* outlines a program to address this problem (see "Strategic Facilities Planning" below).

The historic trend in the space leased off site by the Laboratory has increased as outlined in the preceding section. This increase in space leased off site is reflected in the number of staff housed in leased-space off site, which has risen from 75 in 1986 to 496 in 2003. This option has proven effective for some support units, for example, the warehouse function. However, most other offsite units are somewhat less efficient at offsite locations, and plans to return them to the main site so that they are more readily accessible to researchers have been prepared.

BUILDINGS FOR PROGRAMS AND INFRASTRUCTURE

Berkeley Lab has prepared a *Strategic Facilities Plan* in order to prioritize and guide infrastructure and facility developments to advance the natural and multidisciplinary sciences that have been a key to the nation's prosperity. Modern, effective, and efficient physical infrastructure is critical to maintaining the capabilities of the multiprogram Laboratories and to serve the users of the specialized instrumentation at the Laboratories. This infrastructure and specialized instrumentation has provided first-of-a-kind enabling discoveries and technologies that drive national science and technology advances.

This 10-year *Strategic Facilities Plan* has been prepared to sustain Berkeley Lab's contributions to DOE's mission, and was prepared for DOE's Office of Science as part of its "Laboratories of the 21st Century" initiative. The Plan describes the scientific mission of the Laboratory, and the facilities and infrastructure changes needed to support the planned research mission. The Plan addresses the operational and performance issues that must be addressed to meet the modernization goals described here.

This plan identifies existing and anticipated infrastructure deficiencies, and it proposes actions that can be taken to address these deficiencies before they can have any impact upon the science that is at the core of our mission. Current roles and anticipated changes call for strategic investments in the renewal of the scientific and support infrastructure that is essential for Berkeley Lab to meet its mission and program obligations. The primary portions of the *Strategic Facilities Plan* that apply to the time frame of this Institutional Plan are summarized below.

The priorities established in this strategic planning are based on the science mission and program benefits; the urgency and timing of scientific demand, including the adequacy of existing facilities to satisfy interim needs and avoid risks of program failure; and the potential for improving working conditions and efficiency. The collective strategy and priorities are based on continuing scientific program evaluation and planning, facilities conditions and siting assessments, and a determination of the consequent priorities for facilities planning. Complementary to this planning is the evaluation of projects with a risk-prioritization matrix to assure that program, environmental, safety, and security risks are considered in establishing priorities. The building projects described below include those that have received initial planning or project design and engineering funds, are included as specific initiatives in the plan, or are being considered for third party funding.

Molecular Foundry

The Molecular Foundry will be a National Nanoscale Science Research Center under BES, constituting a key resource for DOE's participation in the National Nanotechnology Initiative (NNI) (see Section IV, Initiatives). The Molecular Foundry conforms to DOE guidance and addresses the research challenges described in the reports *Nanoscale Science, Engineering and Technology Research Directions,* and *Complex Systems: Science for the 21st Century.* Its centerpiece will be a broad array of unique, state-of-the-art facilities in the design, synthesis, and characterization of nanostructures. These facilities, along with an associated scientific and technical staff, will be available for use by collaborators from academic, governmental, and industrial laboratories. Most collaborators will be from Western U.S. institutions, but many of the facilities will be unique nationally and will attract a national constituency. The Molecular Foundry will also serve to educate and train hundreds of undergraduate and graduate students and postdoctoral fellows from educational institutions throughout the West.

The Molecular Foundry's laboratories are designed to facilitate collocation of research activities in complementary fields as required for progress in this new area of science. It will support a research effort focusing primarily on the conjunction of "hard" (nanocrystals, tubes, and lithographically patterned structures) as well as "soft" nanometer-sized materials (polymers, dendrimers, DNA, proteins, and whole cells). Its second major research focus will be the design, fabrication, and study of multicomponent, complex, functional assemblies of these hard and soft nanostructures.

By functioning as a portal to Berkeley Lab's established major user facilities, the Molecular Foundry will leverage existing nanoscience research capabilities at the Advanced Light Source, National Center for Electron Microscopy, and National Energy Research Scientific Computing Center. The research program will, as an additional benefit, provide significant educational and training opportunities for students and postdoctoral fellows of the first generation of nanoscientists. (See Section IV, Initiatives.)

User Support Building

The new User Support Building will provide critically needed modern research support space for users of the Advanced Light Source and other national user facilities. The building will support research in all disciplines (condensed matter physics; chemistry; materials; environmental, and earth sciences; biology; atomic and molecular physics; plasma sciences nanosciences, etc.). The new multiuser structure includes a high bay for assembly of experimental apparatus, as well as modern analytical laboratory and office space to support the over 2,000 scientific facility users. This space will support activities to prepare experiments and to address other critical but short-term high-activity work activities. Demolition of substandard space and improved productivity combine for a payback of approximately seven years. This new 30,000 gsf building will replace Building 10, a wooden 15,575 gsf structure constructed as a service building during WWII, and which contains structural and life safety elements that restrict use. Building 10 can not be cost-effectively upgraded to serve modern science requirements. The estimated cost is $20M.

Research Support Building

The Research Support Building will bring a variety of essential research support functions to a central area where these services can be efficiently managed and easily accessed by all staff and guest researchers. This new building will house key Laboratory research support service functions that are now scattered across the site. This 25,000 gsf building will house ~70 people from a variety of essential research support functions, including Library Services, the Center for Science and Engineering Education, Technology Transfer, the Procurement Department, and the Patent Department. Relocation of these functions from existing research buildings will free up ~20,000 gsf of research space and result in operational cost savings, efficient management, and improved access for staff and guest researchers. The estimated cost is $15.5M.

THIRD-PARTY FUNDED BUILDINGS

Research Office Building

In conjunction with the University of California Office of the President, the Laboratory has recently participated in an assessment of third-party funding options for the construction of new buildings. For the last several decades, the Laboratory has experienced steady growth in its research programs. Despite federal investments by the Department of Energy—especially the Office of Basic Energy Sciences and the Office of Biological and Environmental Research—in modern laboratory and office facilities, the University continues to operate Berkeley Lab with considerable outdated and overcrowded research and office space. While the University's third-party project will not address the total problem, it can relieve some of the pressures.

A building site for an office building has been selected, an architectural program has been developed, and a Request for Qualification (RFQ)/Request for Proposal (RFP) process has been completed for a 60,000 gsf office building. The proposed building site is a slope located adjacent to the Building 50 complex. The expected useful life of the building is 40 years. All basic site utilities exist in proximity to the site. If plans move forward, following a University Ground Lease to a developer, it is anticipated that the developer will prepare final design drawings, finance, construct, and operate the building. The Laboratory will fully lease the facility. Pending identification of an actual name, this project is designated Building 50X in reference to its proposed location near the Building 50 complex.

User Dormitory

Berkeley Lab's Advanced Light Source and National Center for Electron Microscopy (NCEM) are host to a growing number of users—more than 1,600 this year. Many other scientific visitors come to work with researchers in laboratories at other locations across the site, and although most computational scientist utilize NERSC Center facilities remotely, many visit NERSC Center scientific and support staff. In addition, beginning 2007, the Molecular Foundry is expected to host hundreds of users annually. All of these users need dormitories in close proximity to their research to effectively and efficiently conduct their experimental and scientific programs. Working with the University of California Office of the President, Berkeley Lab is developing the scope and approach for third-party support of a dormitory in order to meet these visiting user's short-term housing needs. A central "Civic Center" area location in close proximity to the Advanced Light and a short walk to NCEM, the Molecular Foundry and NERSC Center scientific staff has been identified as an ideal location for the proposed User Dormitory.

Multi-Party Funded Biosciences Research Building

The increased demands for research based on Berkeley Lab's multidisciplinary capabilities in the life sciences has created new needs for laboratories for the biological sciences. The Laboratory is exploring the development of a Biosciences Research Building potentially funded by a combination of foundations, the University of California, and third-party developers. The facility would provide for modern, efficient, and safe conduct of biological research programs at Berkeley Lab and enable quantitative biological science at the scale essential to advances in functional genomics, structural biology, cell biology of cancer, advanced microscopies, and computational biology. This new biology requires a modern facility where biologists, engineers, and computational scientists have a home and work closely together. The proposed facility will include approximately 30 laboratories, 80 offices and dedicated spaces for large shared instrumentation and computing resources in an arrangement that fosters interaction and collaboration. It will be located adjacent the core biosciences buildings in the east canyon and bring the dispersed life sciences programs together. The research conducted in the facilities would include Office of Science research and the complementary research sponsored by other agencies and foundations. The facility would not be a capital project of the Office of Biological and Environmental Research but would be a complementary and valued asset for possible future Genomes for Energy and the Environment: Genomes to Life facilities at Berkeley Lab sponsored by that office.

SCIENCE SUPPORT INFRASTRUCTURE

Berkeley Lab works with the Office of Science as steward for the Laboratory's maintenance and scientific infrastructure to address priority needs for site rehabilitation. Among the most important needs is for more space through more effective utilization, and for addressing the physical legacy of past programs. The Laboratory has an active assets management program to identify and divest materials, equipment, and excess facilities no longer needed at the Laboratory based upon DOE's mission and functions. All assets are tracked and managed.

Removal of Retired Facilities and Asset Management

A critically important effort currently under way at Berkeley Lab in assets management is the removal of Building 51 Bevatron Complex. The project consists of dismantling, demolishing, and any required decontamination of the Building 51 Bevatron Complex. The work includes removal of the accelerator, shielding, buildings, related structures, and surface foundation. This site will then be productively used to meet DOE's emerging scientific missions.

The abandoned Bevatron accelerator cannot be adaptively reused and should be removed. The Bevatron comprises 125,000 gsf (excluding 51B, F & L structures, demolition begun in FY 2004) of Laboratory space, about 7.5 percent of the space on the main site. Since it ceased operation in 1993, the Bevatron had been largely abandoned by the Department of Energy, with very limited funds for its dismantling. A key element of the facilities planning is the deconstruction of the Bevatron facility so this costly maintenance nuisance and impediment to site management can be eliminated, and the site used for DOE research and Laboratory needs. DOE has indicated that the full Bevatron dismantling should proceed, beginning in 2006. To achieve this end, the Laboratory has prepared CD-0 documentation for the Office of Science.

In addition, a number of the early WWII-era buildings are no longer fully functional. These buildings are typically small wooden structures, yet they occupy prime sites that could be redeveloped to accommodate large modern research facilities in line with modern DOE mission requirements. Over the next decade, the Laboratory will vacate these structures so they can be demolished in an orderly manner. The Laboratory proposes a retirement schedule for these structures that allows current building occupants to be relocated into more modern and appropriate space. The Laboratory proposes to reuse these building sites to construct modern multistory research facilities at these locations in order to seamlessly meet DOE's mission requirements for many decades.

Infrastructure, Roads, and Utilities

In order to meet the needs of the Laboratory's scientific programs and to conduct operational and administrative support, general purpose facilities infrastructure is required. This includes the operations function; general engineering support; general computing support infrastructure; service needs for personnel, including environmental, health, and safety resources; property protection and emergency services; transportation services; cafeteria and conference services; and other infrastructure needs. The following buildings are important elements of Berkeley Lab's plan for the FY 2004–2008 time frame.

- **Building 77—Rehabilitation of Building Structure and Systems, Phase 2**. A funded project, FY 2003 start. This project is the second phase of a two-phase project intended to fully rehabilitate Building 77 and 77A as high-precision fabrication, testing, and assembly facilities. Phase 1, funded in 1999, has corrected structural deficiencies in Building 77. Phase 2 will rehabilitate mechanical, electrical, and architectural deficiencies in Buildings 77 and 77A. These two buildings are the center of the Laboratory's engineering support functions. These large structures contain 78,500 gsf of engineering high-bay. Specialized capabilities include numerically controlled precision machining, structural and precision welding of both common and exotic metals, sheet metal fabrication, metal sandblasting and painting, ultra-high-vacuum cleaning and testing, ceramics, machine tool repair, and large-apparatus precision assembly. These capabilities are in high demand within the DOE research and development community, and are not readily available from commercial vendors. Consequently, the buildings currently operate at capacity, and double shifts are necessary to handle the workload. Recent projects have served the needs of the Office of High Energy and Nuclear Physics, the Office of Health and Environmental Research, the National Institutes of Health, and the Office of Basic Energy Sciences. The estimated cost is $13.36M.
- **Building 62—Rehabilitation of Building Operating Systems.** The scientific utility of Building 62, a forty-year old laboratory building, is severely limited by inadequate and deficient building systems. This rehabilitation project will eliminate operational problems that present hardships to researchers and correct structural safety issues, and will ensure many additional decades of beneficial scientific use of this otherwise fine research building. This project will improve operational performance and safety, replace aged wooden fume hoods, install a new centralized laboratory exhaust system, and make other heating ventilation and air conditioning (HVAC) modifications to allow for constant air temperature and pressure conditions in the laboratories. The project will also upgrade the low-conductivity water (LCW) system to meet modern chemistry research requirements and rehabilitate the infrastructure of a primary but aged laboratory building so that it is able to meet the fundamental operational expectations of current and future researchers, consistent with modern life safety and engineering design standards. This project has an estimated cost of $10M.
- **Seismic Roadway and Utility Infrastructure Project.** Portions of the Laboratory roadway system are prone to slip, slide, and fail during an earthquake. Moreover, roadways also serve as the Laboratory's primary utility corridors, and roadway failures can curtail important utility services to large portions of the Laboratory. This project will modify the roadway system to withstand seismic forces and preserve the integrity of the underlying utility infrastructure. This project will reinforce failure-prone areas, modify sections of the storm sewer system so that water flows do not exacerbate failure tendencies, and establish a route of Laboratory ingress and egress specifically designed to operate after a seismic event. Upon completion of this project, the Laboratory

roadway, and the associated utility corridors, will not fail in a seismic event. The estimated cost is $15M.

- **Site Mechanical Utilities Rehabilitation.** Berkeley Lab's infrastructure piping systems for natural gas, low-conductivity water (LCW), compressed air, and storm drainage serve over 100 buildings and facilities, including two major user facilities and four national user facilities. Corrosive soil conditions have caused leaks and failures in underground sections of these piping systems, resulting in excessive maintenance costs and the potential for serious disruptions of mission-critical research and hazards to life safety. By replacing some parts of these systems and installing cathodic protection for other parts, Rehabilitation of Site Mechanical Utilities, Phase 2, will economically prevent failures and arrest deterioration due to corrosion. This will extend system life and assure system performance and integrity during normal operations as well as during fire and earthquake emergencies. The estimated cost is $10.2M.
- **Replace Building 25.** Building 25 is an assembly of building additions surrounding a core building constructed during World War II. This 27,975 gsf dry lab and office building does not meet seismic safety standards and would not be useable after a significant earthquake. This building is located at the very center of the Laboratory and continues to be central to much of the research work performed at the Laboratory. This project will demolish the existing building and construct a replacement 25,000 gsf office and support services building at a nearby site. This new building will allow approximately half of the Laboratory support staff who are currently housed in off site leased space to be located in a seismically safe building on the main site. This building will improve overall service quality while also reducing lease costs. The estimated cost is $20M.

Energy Utility Infrastructure Projects

The Laboratory continues to operate an aggressive program aimed at managing utility costs in a responsible manner. The Facilities Division has managed the investment of over 18 million dollars of Laboratory, utility, third-party, and Federal Energy Management Program (FEMP) funds to achieve a high degree of energy efficiency. Moreover, this Facilities program works closely with DOE to identify lower cost energy providers and ensure reliable energy supply services. In FY 2003, the average cost of electricity to the researcher is 10.3 cents per kilowatt-hour at the main Hill site—attractive relative to the regional and national averages. The Laboratory is currently investigating options, including photovoltaics and hybrid cogeneration, which might allow it to cost-effectively reduce peak electrical demand.

The Laboratory has also ensured that the researchers will not be subject to the rolling blackouts that some predicted would hit California in the future. The Laboratory has installed a two-megawatt standby generator in order to participate in the local utility's Optional Binding Mandatory Curtailment (OBMC) program. Under the OBMC program, the Laboratory will operate this generator rather than curtailing power use during rolling blackouts.

The Laboratory will continue to seek opportunities to improve its physical plant and reduce operating costs while also providing reliable service to the research community.

Information Technologies Infrastructure

Berkeley Lab has prepared a detailed Strategic Plan to address the long-term requirements in support of its Information Technologies, which is briefly summarized above in Section V.

Sustainable Design

Berkeley Lab follows the Executive Order 13123 on “Greening of America” by promoting environmentally responsible design and construction. The environmental impact of new construction is reduced through paying attention to sensitive site development, water and energy conservation, indoor air quality, waste reduction, and environmentally responsible building materials that minimize environmental impact throughout their life cycle.

Green buildings provide a healthy and environmentally responsible workplace. It is Berkeley Lab’s goal to qualify for a Leadership in Energy and Environmental Design (LEED) rating in design and construction of new buildings. LEED Green Building Rating System is developed and administered by U.S. Green Building Council.

Berkeley Lab has been widely recognized for its innovative and effective recycling and reuse programs, efforts that span across all aspects of the Laboratory’s operations. In addition to the conventional paper and metal recycling programs, laboratory chemicals are made available for reuse whenever this is proper, and former shielding blocks are reused within the DOE complex where possible. These programs are summarized in an annual performance measure report to DOE.

INTEGRATED PLANNING PRIORITIES

The Laboratory has established initial priorities for the identified projects. These priorities are reflected in the proposed schedule of projects shown in the Major Construction Projects Table. See Table VI (2). The priorities are based on risk prioritization and management evaluation of relative impact for DOE missions, timing of demand and risk to mission performance, and potential for improving conditions and efficiencies. All the projects identified have high scientific and operational benefit to address significant risk, and very high efficiency gain. Their relative prioritization primarily reflects the immediacy of scientific and user demands.

All projects will be reviewed to support DOE’s compliance with the National Environmental Policy Act (NEPA) and UC’s compliance with the California Environmental Quality Act (CEQA). Construction projects and operations strive to (1) prevent damage to the environment from research and development and construction activities, (2) attain beneficial uses of the Laboratory environment and site, and (3) reduce the risk of undesirable or unintended environmental consequences. The buildings included in this plan can be readily accommodated on the 200-acre Laboratory main site. See map, Figure VI (6). The replacement of single- or two-story buildings with multi-story buildings improves site efficiency, access and circulation, environmental quality, and emergency response.

Table VI (2) Major Construction Projects and Operating Funds for Retired Facilities Removal (FY 2003–2009)

Project	Change in Area (GSF)			Budget ($ in Millions)					
	New Const.	Demolition	Net	TEC[a]	2004	2005	2006	2007	2008
Funded Program Related Projects[b]									
Molecular Foundry (BES)	98,000	0	98,000	83.70	35.00	32.09	9.78		
Funded Science Lab Infrastructure (SLI) Projects (KG)									
Building 77 Rehabilitation of Building Structure & Systems, Phs 2				13.36	2.00	9.60			
Proposed Science Lab Infrastructure (SLI) Projects									
User Support Building	30,000	17,455	12,545	20.00		2.80	16.70	0.30	0.20
Building 62 — Rehabilitation of Building Operating Systems				10.00			1.10	8.00	0.90
Research Support Building	25,000	15,173	9,827	15.50			1.60	13.00	0.90
Seismic Roadway and Utility Infrastructure Project				15.00				1.50	13.00
Operations Building	25,000	16,975	8,025	16.00				2.00	13.00
Site Mechanical Utilities Rehabilitation				10.20					1.50
Replace Building 25 (Seismic Stability)	25,000	27,975	–2,975	20.00					2.00
SLI Line Item Projects Subtotal:	*105,000*	*77,578*	*27,422*		*0.00*	*2.80*	*19.40*	*24.80*	*31.50*
Proposed Third-Party Funded Projects									
Research Office Building			TBD	TBD					
User Dormitories			TBD	TBD					
Multi-Party Funded Biosciences Research Building			TBD	TBD					
Operating Funding Needed For Removal of Retired Facilities									
Removal of Building 51 Bevatron Complex[c]		171,252	-171,252	74.45	7.40	8.60	10.00	10.00	10.00
Removal of Accelerator and related equipment from Building 71				3.00	3.00				
Removal and Site Remediation: Buildings 4, 5, 7, 14, 16, 52, etc.[d]		62,709	–62,709	10.00			5.00	5.00	
Operating Funded Removal of Retired Facilities Subtotal:		*233,961*	*–233,961*		*10.40*	*8.60*	*15.00*	*15.00*	*10.00*
Total net change in GSF	*203,000*	*311,539*	*–108,539*						

[a]Some projects have funding profiles which include years prior to or after the term shown on this table.

[b]Does not include a possible future Genomes for Energy and the Environment: Genomes to Life facility whose scope has yet to be determined.

[c]Total area of Bevatron includes 51B and L structures where demolition began in FY2004, as well as 51F. These figures reflect spring 2003 funding plans using SLI operating funds. Under the current funding scenario final demolition will occur in 2014/15. In late 2003, DOE requested that Berkeley Lab submit a Mission Need Statement for a demolition Line Item Project starting in FY 2006, the table will be updated to reflect DOE's review of this document in 2004.

[d]Project under review, scope and budget are preliminary, final figures will be prepared before the end of 2003.

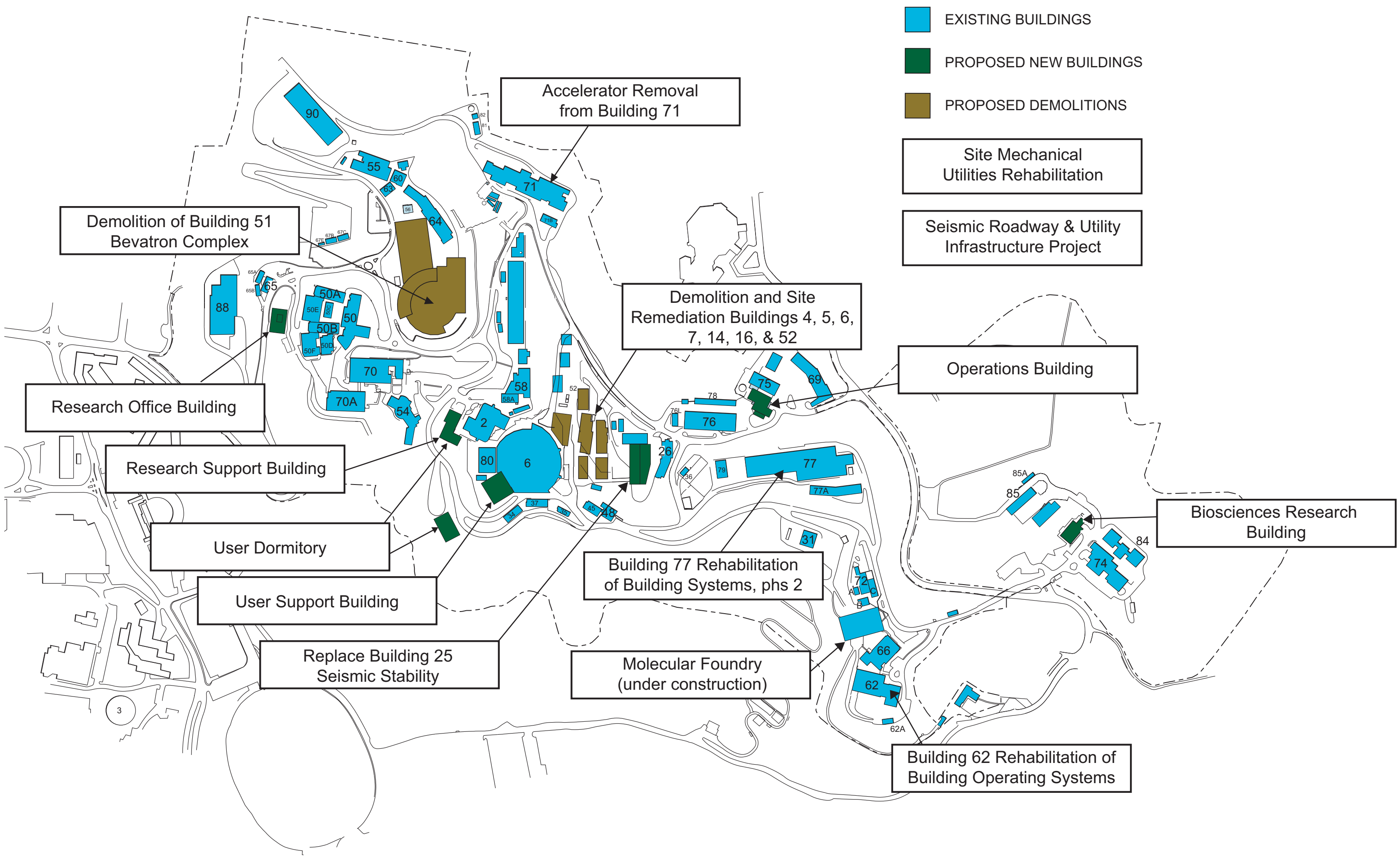

Figure VI (6) Map of Science Line Infrastructure (SLI) and Programmatic Line item construction projects, and projects to remove retired facilities, as identified in Table VI (2).

VII. SUMMARY OF MAJOR ISSUES

This Summary of Major Issues section is included in the Institutional Plan as background information on institutional issues to be addressed at the Berkeley Lab DOE Institutional Planning On-Site Review. Berkeley Lab issues are addressed regularly through meetings and discussions with DOE management at the Berkeley Site Office and DOE Headquarters within DOE's realigned Office of Science (SC) management framework.

A number of issues relate to DOE management activities that are being promulgated outside of the Office of Science line management organization, including new cybersecurity, physical security, safety, and administrative requirements. Other issues arise from the difficulties in establishing priorities for a legacy of limited capital investment. Topics not addressed in this section are the programmatic priorities for Berkeley Lab, which are described in Sections I through IV. Institutional issues that need to be addressed are discussed below.

PRINCIPLES FOR OFFICE OF SCIENCE CONTRACTS

DOE and the Administration are committed to improving management efficiencies, eliminating redundancy, and focusing on results. In April of last year, Under Secretary of Energy Robert G. Card issued a comprehensive set of best-practices-based principles to advance both the institutional performance under, and the contract administration of, the Office of Science Laboratory Contracts. These principles offer the prospects for (1) clear Departmental line-management accountability, (2) primary reliance on nationally recognized laws, regulations, and standards to establish Laboratory performance criteria and to set Laboratory administrative and operational requirements, (3) systems-based approaches to compliance assurance and performance oversight using external, nationally recognized expertise and independent validation/ certification experts, (4) Laboratory adoption of best-in-class business practices, integrated administrative and operating systems, and external formal certification of business methods where feasible, (5) a five-year compelling Vision for the Laboratory and a work plan that realizes the Vision's goals and mission objectives, and (6) Laboratory incentives (financial and nonfinancial) promoting improved accountability and performance.

The Office of Science (SC) and supporting DOE offices have worked to incorporate these six principles in the forthcoming contract for management and operation of the SC national laboratories by authoring new prime contract clauses reflecting specific principles; deleting or revising legacy clauses that conflict with the principles and/or the new, stronger line management responsibilities and accountabilities; modifying scope-of-work areas of the contract to highlight the vision, work plan, and work-scope deliverables; and streamlining the use of DOE's unique work criteria, business practices, and performance standards. The objective is to have both the federal contract terms and oversight methods, and the institution's management systems and operating practices, tailored towards meeting the needs and supporting attainment of the Laboratory Vision. For the Berkeley Lab contract, the Laboratory has participated in SC's Model Contract working sessions and contributed ideas and concepts for tailoring both the Model Contract and the DOE Directives to the characteristics and criteria of this institution.

ACCOUNTABLE BUSINESS PRACTICES

Berkeley Lab has conducted reviews of a number of its administrative systems so that business activities are executed with a high degree of accountability. We have taken specific steps to improve practices in procurement and property management. The use of procurement cards has been dramatically restructured for improved accountability. For example, we have significantly reduced the number of purchasing cards, increased training, and improved accountability at all levels. All purchases are double checked with additional approval steps required.

We are also strengthening accountability in other purchasing systems and are adding additional receiving and documentation requirements to assure the ability to locate and verify the proper use and disposition of all property. Our corrective action plan has been implemented and shared with appropriate DOE and UC Office of the President authorities. Even prior to these stages, our identified wall-to-wall inventory found more than 99.5 percent of federal property, and there was no evidence of fraud or theft in the unaccounted items.

We understand that new expectations are aimed for zero unaccounted items, and our new system is directed to that goal. Consistent with our values for full accountability, Berkeley Lab management has given a clear message to all employees that all inquiries should be addressed with cooperation, honesty, and integrity as our highest priorities. Those who find potential problems or questions with procedures are encouraged to come forward and share that information with a supervisor or senior manager—and do so with the assurance that reporting such actions will not result in recrimination or retaliation of any kind. The Laboratory strives to be fully aware of any problems, so that they can be promptly addressed.

BEVATRON DECONSTRUCTION

The Bevatron was constructed as a 6 GeV proton accelerator in 1954 and became a workhorse for the Office of Science during an illustrious scientific career. The Bevatron was the site for the discovery of the antiproton in 1956, for the particle reasonances in the early 1960s, and combined in the 1970s with the Super Heavy Ion Linear Accelerator (SuperHILAC) to found the fields of relativistic heavy-ion physics and heavy-ion radiotherapy. Since its decommissioning in 1993, it had largely been abandoned by the Office of Science, sitting as a cement-and-steel sarcophagus. It is located in the most central part of Berkeley Lab on scientifically valuable property under the Office of Science jurisdiction. The buildings make up about 10 percent of the total building space on the Berkeley Lab site. The accelerator consists of 20,000 tons of concrete shielding and 11,000 tons of metal. Several small projects have removed some of the shielding blocks and several interior structures, and funds have been received in FY 2003 for dismantling the independent external beam hall. However, substantial resources are needed to achieve a full plan for Bevatron dismantling (see Section VI). DOE has indicated that the full Bevatron dismantling should proceed, beginning in 2006. To achieve this end, the Laboratory has prepared CD-0 documentation for the Office of Science.

NEW BUILDINGS FOR DOE MISSIONS

The construction of new research and office buildings is critical to achieving the Laboratory's science mission. The buildings included in Berkeley Lab's strategic facilities planning are based on scientific drivers for DOE missions. In a number of instances, without new scientific investments that advance the research frontier, many of the existing unsatisfactory and decaying buildings threaten the scientific contributions to the program offices.

Several key proposed buildings highlight this need. The Molecular Foundry (described in Sections IV and VI) is a programmatic building that supports the national priorities in nanoscience, and is being constructed on the basis of merit review within a framework of priorities established by the Office of Science and the Office of Basic Energy Sciences. The implementation of the 150 Teraflop computer system will require a building to house the facility at Berkeley Lab. Two other buildings are to be supported by the Science Lab Infrastructure program—a User Support Building that replaces a wood frame World War II structure, and a Research Support Facility that replaces a demolished building and provides adequate space for Berkeley Lab's research infrastructure.

The University of California Office of the President, with Berkeley Lab, is also advancing third-party financing of office space and user dormitories. The Laboratory is also exploring combinations of foundation support, third party and university support for high demand research in the biological sciences and other areas. The Laboratory believes that a range of options must be pursued to address the need for new buildings, both to replace condemned or obsolete buildings and to provide additional space.

ADEQUATE RESOURCES FOR MAINTAINING INFRASTRUCTURE

Infrastructure investments at Berkeley Lab are essential to maintain and rehabilitate buildings, utility systems, roads, and parking. At Berkeley Lab, more than 70 percent of the current government-owned space was constructed before 1970, when the Laboratory was a single-purpose Atomic Energy Commission facility. The average building age is 37 years and, of the 1.77 million square feet of existing building space, approximately 299,000 square feet is rated "Fail" and is in need of replacement.

With Berkeley Lab's landlord—the High Energy and Nuclear Physics Program and Stewardship Committee—we are working to address the general infrastructure needs of the Laboratory. Central to this issue is securing the necessary infrastructure investments to sustain efficient, safe, and cost-effective operational requirements. General Plant Project funding, General Purpose Equipment, and the Science Facilities Infrastructure program have been essential to address vital requirements, but the level of resources has been inadequate to meet existing needs. Increased support or new approaches to funding infrastructure are needed to meet critical needs, including replacement of existing abandoned structures, upgrading utilities, and rehabilitating building systems.

Increasing the maintenance budget while prohibiting maintenance expenditures that are "betterments" is not an effective strategy for a laboratory with major portions of its infrastructure constructed in a different era of science. Increased maintenance expenditures must be coupled with fiscal policy that allows upgrades to structural, mechanical, and architectural systems. Further information on this topic is provided in Section VI, which addresses "Infrastructure Strategic Planning."

COUNTERINTELLIGENCE AND SECURITY FOR A TIER III LABORATORY

The Laboratory works to assure that its personnel and visitors are safe and that its assets—intellectual, property, computational, and other resources—are properly protected for its Office of Science mission and operational requirements. Berkeley Lab has been working with DOE's Office of Science and Berkeley Site Office to assure that effective and well-tailored security measures are provided for Tier III laboratories, all of which have no classified information and serve the nation's scientific community. The Laboratory has provided briefings and information on this topic to the germane Office of Science and DOE support offices, the Laboratory Operations Board, and the University of California Office of the President's Laboratory Security Panel, as examples. Berkeley Lab is fully committed to an effective security program that is commensurate and aligned with its Office of Science mission as a Tier III laboratory. Berkeley Lab management seeks to reinforce effective line management and to be held accountable for security performance that is aligned with security risks. Further information on Berkeley Lab's security programs is included in Section V.

FUNDING FOR ENVIRONMENTAL RESTORATION

DOE's Office of Environmental Management (EM) has ended programmatic support of Berkeley Lab's Waste Management program and Lab's Environmental Restoration Program in 2006. This latter action raises the important questions the Lab is now studying: Will the Office of Science be able to afford long-term stewardship that is consistent with the commitments made to state and local regulatory agencies and to the public? In addition, if subsurface contamination is later found, would the Office of Science provide a funding remedy in currently inaccessible areas? There are important issues in considering any transition in funding.

VIII. RESOURCE PROJECTIONS AND TABLES

Resource projections for the Institutional Plan provide a description of the budget authority (BA) to implement the research programs. The resource tables also indicate actual fiscal year (FY) 2002 and FY 2003 budget authority for comparison. These tables include:

- Resources by Major Program:

  Laboratory Funding and Personnel Summaries, Tables VIII (1)(a)–(b)
  Funding and Personnel by Secretarial Officer, Tables VIII (2)(a)–(b)
  Office of Science Funding and Personnel, Table VIII (3)(a)
  Energy Efficiency and Renewable Energy Funding and Personnel, Table VIII (3)(b)
  Fossil Fuel and Other DOE Program Funding and Personnel, Table VIII (3)(c)
  Reimbursable Work, Table VIII (3) (d)
  Work for Others Funding and Personnel, Table VIII (4)
- Subcontracting and Procurement, Table VIII (5)(a)
- Small and Disadvantaged Business Procurement, Table VIII (5)(b)
- Experimenters at Designated User Facilities (FY 2001), Table VIII (6)
- University and Science Education, Table VIII (7)
- Laboratory Directed Research and Development, Table VIII (8)

The FY 2004 estimate was prepared in Spring 2003, and is based on DOE budget guidance, the President's Request, and assessments by Berkeley Lab Divisions. For fiscal years 2004 and beyond, operating cost projections are in FY 2003 dollars, and construction costs are in actual-year dollars (as indicated in the DOE guidance). For FY 2004 to FY 2008, the growth assumptions in program areas as tabulated range from 3% to 1.5% per year. These growth assumptions are based on the general direction indicated by DOE program personnel.

Specific trend levels have been established within each program activity. Projections in FY 2004–2007 includes planned funding for the Molecular Foundry project in Office of Basic Energy Sciences (B&R: KCO2). The projections exclude research subcontracts and other collaborative activities that might be conducted by other institutions outside of Berkeley Lab.

The resource projections that follow include all funded and budgeted construction projects, the projected General Purpose Facilities program, and the approved Environmental Restoration and Waste Management program funding. Some reporting summary levels may have slight differences in totals due to rounding. Resource projections for new initiatives are presented in Section IV and are not included in this section unless incorporated in budget submissions. Construction project cost details are provided in Section VI.

Table VIII (1) (a) Laboratory Funding Summary ($ in Millions-BA)

	FY02	FY03	FY04	FY05	FY06	FY07	FY08
DOE Effort	306.2	292.6	358.2	386.1	418.3	419.8	429.3
Homeland Security	–	–	2.2	2.3	2.3	2.4	2.4
WFO	95.1	97.0	117.2	121.2	122.9	125.4	127.8
CRADA	3.3	1.0	1.1	1.7	1.9	0.9	0.9
Total Operating	**404.6**	**390.6**	**478.7**	**511.3**	**545.4**	**548.5**	**560.4**
Capital Equipment	50.0	47.2	49.3	67.9	56.7	58.0	58.1
Program Construction	7.6	10.8	38.7	37.6	16.0	5.6	4.7
General Purpose Facilities	4.4	4.5	2.0	12.4	18.2	12.2	15.1
General Plant Projects	3.3	3.5	3.5	3.5	3.5	3.5	3.5
General Purpose Equipment	1.9	2.0	2.0	2.0	2.0	2.0	2.0
Total Lab Funding	**471.8**	**458.6**	**574.2**	**634.7**	**641.8**	**629.8**	**643.8**

Table VIII (1) (b) Laboratory Personnel Summary (FTE)

	FY02	FY03	FY04	FY05	FY06	FY07	FY08
DIRECT							
DOE Effort	1,640	1,639	1,700	1,769	1,864	1,869	1,902
Homeland Security	–	–	11	11	11	12	12
Work for Other than DOE	457	495	570	572	557	551	551
CRADA	16	9	7	7	7	3	3
TOTAL DIRECT	2,113	2,143	2,288	2,359	2,439	2,435	2,468
TOTAL INDIRECT	772	773	775	778	783	786	793
Total PERSONNEL	**2,885**	**2,916**	**3,063**	**3,137**	**3,222**	**3,221**	**3,261**

Table VIII (2) (a) Funding by Secretarial Officer ($ in Millions-BA)

	FY02	FY03	FY04	FY05	FY06	FY07	FY08
Office of Science (SC)							
Operating	240.7	235.5	283.5	310.9	340.0	341.8	351.8
Capital Equipment	49.9	49.2	51.3	69.9	58.7	60.0	60.1
Construction	10.9	17.3	42.8	53.0	37.7	21.3	23.3
Total	**301.5**	**302.0**	**377.6**	**433.8**	**436.4**	**423.1**	**435.2**
Assistant Secretary for Energy Efficiency and Renewable Energy (EE)							
Operating	29.2	27.2	33.2	36.4	37.7	38.3	39.5
Capital Equipment	0.9	–	–	–	–	–	–
Total	**30.1**	**27.2**	**33.2**	**36.4**	**37.7**	**38.3**	**39.5**
Assistant Secretary for Fossil Energy (FE)							
Operating	7.5	5.5	7.6	8.7	10.5	11.9	11.9
Total	**7.5**	**5.5**	**7.6**	**8.7**	**10.5**	**11.9**	**11.9**
Assistant Secretary for Environmental Restoration (EM)							
Operating	7.3	3.6	4.5	5.2	5.1	3.0	3.1
Total	**7.3**	**3.6**	**4.5**	**5.2**	**5.1**	**3.0**	**3.1**
National Nuclear Security Administration (NA)							
Operating	6.1	5.6	6.9	4.6	4.5	4.1	4.1
Total	**6.1**	**5.6**	**6.9**	**4.6**	**4.5**	**4.1**	**4.1**
Office of Intelligence (IN)							
Operating	–	0.1	0.2	0.2	0.2	0.2	0.2
Total	**–**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Assistant Secretary for Environment, Safety and Health (EH)							
Operating	0.6	0.4	0.5	0.6	0.6	0.6	0.6
Total	**0.6**	**0.4**	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**
Work for Other DOE Contractors							
Operating	14.9	14.7	21.8	19.5	19.7	19.9	18.1
Capital Equipment	1.1	–	–	–	–	–	–
Construction	4.4	1.5	1.4	0.5	–	–	–
Total	**20.4**	**16.2**	**23.2**	**20.0**	**19.7**	**19.9**	**18.1**
Total DOE							
Operating	306.3	292.6	358.2	386.1	418.3	419.8	429.3
Capital Equipment	51.9	49.2	51.3	69.9	58.7	60.0	60.1
Construction	15.3	18.8	44.2	53.5	37.7	21.3	23.3
Total	**373.5**	**360.6**	**453.7**	**509.5**	**514.7**	**501.1**	**512.7**

Table VIII (2) (b) Personnel by Secretarial Officer (FTE)

	FY02	FY03	FY04	FY05	FY06	FY07	FY08
Office of Science (SC)							
Direct FTE	1,302	1,311	1,362	1,412	1,495	1,503	1,531
Assistant Secretary for Energy Efficiency and Renewable Energy (EE)							
Direct FTE	144	148	157	171	178	180	185
Assistant Secretary for Fossil Energy (FE)							
Direct FTE	38	38	38	43	48	53	53
Assistant Secretary for Environmental Restoration (EM)							
Direct FTE	37	28	26	26	26	17	17
National Nuclear Security Administration (NA)							
Direct FTE	31	21	23	23	23	22	22
Office of Intelligence (IN)							
Direct FTE	–	1	1	1	1	1	1
Assistant Secretary for Environment, Safety and Health (EH)							
Direct FTE	3	2	3	3	3	3	3
Work for Other DOE Contractors							
Direct FTE	85	90	90	90	90	90	90
Total DOE							
Direct FTE	**1,640**	**1,639**	**1,700**	**1,769**	**1,864**	**1,869**	**1,902**
Homeland Security							
Direct FTE	–	–	11	11	11	12	12
Work for Others—Non-DOE							
Direct FTE	457	495	570	572	557	551	551
CRADA							
Direct FTE	16	9	7	7	7	3	3
TOTAL LAB DIRECT	**2,113**	**2,143**	**2,288**	**2,359**	**2,439**	**2,435**	**2,468**

Table VIII (3) (a) Office of Science Funding ($ in Millions-BA) and Personnel (FTE)

	FY02	FY03	FY04	FY05	FY06	FY07	FY08
AT Fusion Energy Sciences							
Operating	5.6	5.8	5.6	5.6	5.5	5.5	5.5
Capital Equipment	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Construction	–	–	–	–	–	–	–
Total	**6.0**	**6.2**	**6.0**	**6.0**	**5.9**	**5.9**	**5.9**
FS Field Security							
Operating	4.7	4.7	4.7	4.7	4.8	4.9	5.0
Total	**4.7**	**4.7**	**4.7**	**4.7**	**4.8**	**4.9**	**5.0**
KA High Energy Physics							
Operating	28.8	21.5	29.1	35.1	35.3	36.5	41.9
Capital Equipment	12.0	17.8	21.0	22.0	23.0	24.0	25.0
Construction	3.3	3.5	3.5	3.5	3.5	3.5	3.5
Total	**44.1**	**42.8**	**53.6**	**60.6**	**61.8**	**64.0**	**70.4**
KB Nuclear Physics							
Operating	16.7	17.7	15.7	16.7	17.4	17.8	18.1
Capital Equipment	2.8	2.4	4.9	8.0	8.0	6.4	2.0
Construction	0.4	0.4	–	0.4	0.4	0.4	0.4
Total	**19.9**	**20.5**	**20.6**	**25.1**	**25.8**	**24.6**	**20.5**
KC02 Material Sciences							
Operating	50.6	54.9	67.2	75.0	97.2	93.1	93.6
Capital Equipment	10.5	14.6	9.6	8.9	8.5	10.4	10.6
Construction	2.6	8.9	37.3	36.7	15.6	5.2	4.3
Total	**63.7**	**78.4**	**114.1**	**120.6**	**121.3**	**108.7**	**108.5**
KC03 Chemical Science							
Operating	15.8	15.8	19.7	20.6	21.8	22.9	24.0
Capital Equipment	2.5	2.5	1.3	1.4	1.5	1.5	1.7
Total	**18.3**	**18.3**	**21.0**	**22.0**	**23.3**	**24.4**	**25.7**
KG Science Laboratory Infrastructure							
Operating	2.5	2.5	3.0	4.0	4.0	4.0	4.0
Construction	4.4	4.5	2.0	12.4	18.2	12.2	15.1
Total	**6.9**	**7.0**	**5.0**	**16.4**	**22.2**	**16.2**	**19.1**
KJ Advanced Scientific Computing Research							
Operating	62.3	54.5	62.1	67.9	68.5	69.0	69.2
Capital Equipment	3.6	0.9	7.9	11.5	11.6	11.6	3.7
Construction	–	–	–	–	–	–	–
Total	**65.9**	**55.4**	**70.0**	**79.4**	**80.1**	**80.6**	**72.9**

Table VIII (3) (a) Office of Science Funding ($ in Millions-BA) and Personnel (FTE) – *cont.*

	FY02	FY03	FY04	FY05	FY06	FY07	FY08
KL Workforce Development for Teachers and Scientists							
Operating	0.5	0.8	1.6	1.7	1.7	1.7	1.7
Total	**0.5**	**0.8**	**1.6**	**1.7**	**1.7**	**1.7**	**1.7**
KP Biological and Environmental Research							
Operating	53.3	57.3	74.8	79.6	83.8	86.4	88.8
Capital Equipment	18.3	10.6	6.2	17.7	5.7	5.7	16.7
Construction	0.2	–	–	–	–	–	–
Total	**71.8**	**67.9**	**81.0**	**97.3**	**89.5**	**92.1**	**105.5**
Total, Office of Science							
Operating	240.8	235.5	283.5	310.9	340.0	341.8	351.8
Capital Equipment	50.1	49.2	51.3	69.9	58.7	60.0	60.1
Construction	10.9	17.3	42.8	53.0	37.7	21.3	23.3
Total	**301.8**	**302.0**	**377.6**	**433.8**	**436.4**	**423.1**	**435.2**
Direct FTE	1,302	1,313	1,362	1,413	1,496	1,503	1,532

Table VIII (3) (b) Energy Efficiency and Renewable Energy Funding ($ in Millions-BA) and Personnel (FTE)

	FY02	FY03	FY04	FY05	FY06	FY07	FY08
EB Solar and Renewable Resource Technologies							
Operating	4.3	4.6	5.8	6.4	6.6	6.9	7.3
Total	**4.3**	**4.6**	**5.8**	**6.4**	**6.6**	**6.9**	**7.3**
EC Building Technology, State and Community Sector							
Operating	14.0	11.4	13.0	13.5	14.1	14.6	15.2
Capital Equipment	0.4	–	–	–	–	–	–
Total	**14.4**	**11.4**	**13.0**	**13.5**	**14.1**	**14.6**	**15.2**
ED Industrial Sector - Total							
Operating	3.1	2.9	2.4	2.4	2.5	2.6	2.7
Capital Equipment	0.2	–	–	–	–	–	–
Total	**3.3**	**2.9**	**2.4**	**2.4**	**2.5**	**2.6**	**2.7**
EE Transportation Sector							
Operating	4.6	5.3	8.6	10.6	11.0	10.4	10.5
Capital Equipment	0.3	–	–	–	–	–	–
Total	**4.9**	**5.3**	**8.6**	**10.6**	**11.0**	**10.4**	**10.5**
EL Federal Energy Management Program							
Operating	2.7	2.8	3.0	3.0	3.0	3.2	3.3
Total	**2.7**	**2.8**	**3.0**	**3.0**	**3.0**	**3.2**	**3.3**
EO Power Technologies							
Operating	0.6	0.2	0.5	0.5	0.5	0.5	0.6
Total	**0.6**	**0.2**	**0.5**	**0.5**	**0.5**	**0.5**	**0.6**
Total, Assistant Secretary for Energy Efficiency and Renewable Energy							
Operating	29.3	27.2	33.3	36.4	37.7	38.2	39.6
Capital Equipment	0.9	–	–	–	–	–	–
Total	**30.2**	**27.2**	**33.3**	**36.4**	**37.7**	**38.2**	**39.6**
Direct FTE	144	149	157	171	177	179	184

Table VIII (3) (c) Fossil Energy and Other DOE Program Funding ($ in Millions-BA) and Personnel (FTE)

	FY02	FY03	FY04	FY05	FY06	FY07	FY08
AA Coal							
Operating	1.8	1.6	2.5	3.5	5.2	6.2	5.2
Total	**1.8**	**1.6**	**2.5**	**3.5**	**5.2**	**6.2**	**5.2**
AB Gas							
Operating	1.6	1.8	1.5	1.6	1.6	1.7	1.6
Total	**1.6**	**1.8**	**1.5**	**1.6**	**1.6**	**1.7**	**1.6**
AC Petroleum							
Operating	4.1	2.1	3.6	3.7	3.7	4.0	4.1
Total	**4.1**	**2.1**	**3.6**	**3.7**	**3.7**	**4.0**	**4.1**
Total, Assistant Secretary for Fossil Energy							
Operating	7.5	5.5	7.6	8.8	10.5	11.9	11.9
Total	**7.5**	**5.5**	**7.6**	**8.8**	**10.5**	**11.9**	**11.9**
Direct FTE	38	38	39	44	49	53	53
EW Environmental Restoration and Waste Management—Defense							
Operating	3.0	0.0	1.1	1.2	1.2	1.3	1.4
Total	**3.0**	**0.0**	**1.1**	**1.2**	**1.2**	**1.3**	**1.4**
EX Environmental Restoration and Waste Management—Non-Defense							
Operating	4.2	3.6	3.4	4.1	3.9	1.7	1.7
Total	**4.2**	**3.6**	**3.4**	**4.1**	**3.9**	**1.7**	**1.7**
Total, Assistant Secretary for Environmental Restoration							
Operating	7.2	3.6	4.5	5.3	5.1	3.0	3.1
Total	**7.2**	**3.6**	**4.5**	**5.3**	**5.1**	**3.0**	**3.1**
Direct FTE	37	28	26	26	26	17	17
NN Nonproliferation and Verification R&D							
Operating	6.1	5.6	6.9	4.6	4.5	4.1	4.1
Total	**6.1**	**5.6**	**6.9**	**4.6**	**4.5**	**4.1**	**4.1**
Total, National Nuclear Security Administration							
Operating	6.1	5.6	6.9	4.6	4.5	4.1	4.1
Total	**6.1**	**5.6**	**6.9**	**4.6**	**4.5**	**4.1**	**4.1**
Direct FTE	31	21	23	23	23	22	22

Table VIII (3) (c) Fossil Energy and Other DOE Program Funding ($ in Millions-BA) and Personnel (FTE)—*cont.*

	FY02	FY03	FY04	FY05	FY06	FY07	FY08
IN Office of Intelligence							
Operating	–	0.1	0.2	0.2	0.2	0.2	0.2
Total	**–**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Total, Office of Intelligence							
Operating	–	0.1	0.2	0.2	0.2	0.2	0.2
Total	**–**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**
Direct FTE	–	1	1	1	1	1	1
HD Environment, Safety, and Health (Defense)							
Operating	0.6	0.4	0.5	0.6	0.6	0.6	0.6
Total	**0.6**	**0.4**	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**
Total, Assistant Secretary for Environment, Safety and Health							
Operating	0.6	0.4	0.5	0.6	0.6	0.6	0.6
Total	**0.6**	**0.4**	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**
Direct FTE	3	2	3	3	3	3	3

Table VIII (3) (d) Reimbursable Work ($ in Millions-BA) (FTE)

	FY02	FY03	FY04	FY05	FY06	FY07	FY08
Total, Department of Homeland Security							
Operating	–	–	2.2	2.3	2.3	2.4	2.4
Total	–	–	2.2	2.3	2.3	2.4	2.4
Direct FTE	–	–	11	11	11	12	12

Table VIII (4) Work for Others—Federal Agencies ($ in Millions-BA) and Personnel (FTE)

	FY02	FY03	FY04	FY05	FY06	FY07	FY08
Work for Others—Federal Agencies							
Department of Commerce	0.1	0.1	0.3	0.3	0.4	0.4	0.4
Department of Defense	11.8	7.8	9.4	10.3	10.3	10.3	10.3
Department of Interior	0.1	0.1	0.2	0.2	0.2	0.3	0.3
Environmental Protection Agency	4.0	3.1	4.6	5.2	5.2	5.1	5.3
National Aeronautics and Space Admin.	5.2	5.3	7.7	8.0	8.0	8.0	8.0
National Institutes of Health	43.8	40.6	48.0	48.1	49.0	50.1	51.5
National Science Foundation	0.2	0.2	0.3	0.9	1.7	2.7	2.9
Other Federal Agencies — Energy Related Activities	1.5	0.5	1.1	1.0	1.0	1.1	1.1
Department of Agriculture	–	1.4	1.0	–	–	–	–
Other Federal Agencies	0.4	0.8	–	–	–	–	–
Total Federal Operating	67.1	59.9	72.6	74.0	75.8	78.0	79.8
Total	**67.1**	**59.9**	**72.6**	**74.0**	**75.8**	**78.0**	**79.8**
Work for Others—Non-Federal Agencies							
Universities and Institutes	12.9	16.3	18.9	20.4	20.0	20.0	20.0
State and Local Governments and Non-Profit Org.	9.1	12.2	14.0	15.7	16.2	16.7	17.2
Industry	5.3	7.8	10.8	10.0	10.0	10.0	10.0
Foreign Government	0.8	0.8	1.1	1.0	1.0	0.8	0.8
Total Non-Federal Operating	28.1	37.1	44.8	47.1	47.2	47.5	48.0
Total	**28.1**	**37.1**	**44.8**	**47.1**	**47.2**	**47.5**	**48.0**
Total Work for Others—Non-DOE Contractors							
Operating	**95.2**	**97.0**	**117.4**	**121.1**	**123.0**	**125.6**	**127.8**
Direct FTE	457	495	570	572	557	551	551
CRADA							
Operating	3.3	1.0	1.1	1.7	1.9	0.9	0.9
Direct FTE	16	9	7	7	7	3	3

Table VIII (5) (a) Subcontracting and Procurement ($ in Millions-Obligated)

	FY02	FY03	FY04	FY05
Subcontracting and Procurement from:				
Universities	18.7	19.1	19.5	19.9
All Others	179.9	183.7	187.5	191.5
Transfers to Other DOE Facilities	3.7	3.7	3.9	3.9
Total External Subcontracts and Procurement	202.3	206.5	210.9	215.3

Table VIII (5) (b) Small and Disadvantaged Business Procurement ($ in Millions-BA)

	FY02	FY03
Procurement from Small and Disadvantaged Business	61.5	72.2
Percent of Annual Procurement	39.0%	44.9%
Available Subcontracting Dollars	157.5	160.8

Table VIII (6) Experimenters at Designated User Facilities (FY 2002)

	Number of Experimenters	Number of Organizations	Percentage of Use
Advanced Light Source			
Laboratory	439	12	32
Other DOE Laboratories	62	13	4
Other U.S. Government	3	3	1
University	523	86	38
Industry	130	53	9
Foreign Laboratory	42	30	2
Foreign University	171	83	12
Foreign Industry	12	8	1
Other	3	3	1
Total	**1,385**	**291**	**100**
National Energy Research Scientific Computing Center			
Laboratory	185	12	17
Other DOE Laboratories	538	15	39
Other U.S. Government	84	25	4
University	1,160	170	35
Industry	62	13	3
Other (private labs)	34	7	2
Total	**2,063**	**242**	**100**
88-Inch Cyclotron			
Laboratory	48	4	22
Other DOE Laboratories	22	4	9
Other U.S. Government	12	2	15
University	61	16	23
Industry	38	11	5
Foreign Laboratory	6	4	3
Foreign University	34	12	17
Foreign Industry	9	4	6
Total	**230**	**57**	**100**

Table VIII (6) Experimenters at Designated User Facilities—*cont.*

	Number of Experimenters	Number of Organizations	Percentage of Use
National Center for Electron Microscopy			
Laboratory	73	6	30
Other DOE Laboratories	8	4	4
Other U.S. Government	1	1	1
University	125	26	53
Industry	8	6	4
Foreign Laboratory	1	1	1
Foreign University	16	10	7
Total	**232**	**54**	**100**
Grand Total			
Laboratory	**745**	**34**	**18**
Other DOE Laboratories	**630**	**36**	**9**
Other U.S. Government	**100**	**31**	**1**
University	**1,869**	**298**	**69**
Industry	**238**	**83**	**1**
Foreign Laboratory	**49**	**35**	**<1**
Foreign University	**221**	**105**	**2**
Foreign Industry	**21**	**12**	**<1**
Other	**37**	**10**	**<1**
Total	**3,910**	**644**	**100**

Table VIII (7) University and Science Education

	FY2002			FY2003*		
	Total	Minorities	Women	Total	Minorities	Women
PRE-COLLEGE PROGRAMS						
Student Programs	26	17	11	30	18	15
Teacher Programs	45	4	18	45	4	18
Special Programs**	1000	300	500	3060	1000	1500
UNDERGRADUATE PROGRAMS						
Student Programs	100***	45	45	80***	36	36
Faculty Participating Guests	3	1	0	5	1	0

*Estimate

**Includes precollege participation in the Open House conducted in FY 2003, and outreach through the "Careers in Science" Program

***Includes ethnic group unspecified

Table VIII (8) Laboratory Directed Research and Development Funding ($ in Millions-Estimated Costs)

	FY02	FY03	FY04	FY05	FY06	FY07	FY08
Costs	12.4	10.7	13.0	13.5	14.5	15.0	16.0

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Computing Sciences	Dwayne Ramsey
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Earth Sciences	Linda Wuy
Environmental Energy Technologies	Donald Grether
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Life Sciences	Damir Sudar
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